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HEAT-TRANSFER CHARACTERISTICS OF CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA FLOWING UPWARD IN UNIFORMLY HEATED STRAIGHT TUBES

by R. C. Hendricks, R. J. Simoneau, and R. Friedman

Lewis Research Center
Cleveland, Ohio

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SUMMARY

Some heat-transfer characteristics of cryogenic hydrogen flowing vertically upward in uniformly joule-heated straight tubes were assessed over the pressure range of 1000 to 2500 psia. The fluid appeared to exhibit gas-like behavior in this regime. Heat-transfer data for the most part were predictable to ±20 percent by the Nusselt-film correlation

$$Nu_f = CRe_f^p Pr_f^{0.4}$$

where $C = 0.021$ and $p = 0.8$. A closer examination, however, of the data for each test section indicated that the Reynolds number exponent p can vary between 0.83 and 0.9 with the constant C changed correspondingly from 0.011 to 0.006. These correlations hold for heat fluxes up to 10 Btu per square inch per second, wall-to-bulk temperature ratios to 11, mass-flow rates to 0.4 pound mass per second, film Reynolds number from 10^5 to 4×10^6, and inside tube diameters from 0.21 to 0.438 inch; the effects of length-to-diameter ratio and Mach number were not established under all conditions. Corresponding friction factor data for these test sections are not presented.

A limited amount of data taken while the largest diameter test section (0.438 in.) was in a high frequency lateral oscillation showed a significant increase in heat transfer over that predicted in the previous Nusselt-film correlation. These oscillatory data were excluded from those used to establish the recommended correlation.

INTRODUCTION

Propulsion system developments require heat-transfer information on cryogenic hydrogen above 1000 psia under very severe heat-transfer conditions. A survey of these requirements reveals the extremes in most of the heat-transfer parameters as follows:

(1) Heat fluxes to 30 Btu per square inch per second

(2) Wall-to-bulk temperature ratios to 30

(3) Pressures to 5000 psia

(4) Mass flow rates per engine channel to 1.5 pounds mass per second

(5) Engine channel Mach numbers to 0.8

(6) Nonuniform heating and accelerations introduced by the peculiar channel geometries

Previous investigation of heat transfer to liquid hydrogen in the region of 200 to 800 psia have indicated difficulties in predicting the heat-transfer coefficient. Even though the severe property variations associated with the critical point are diminished at increased pressure, which indicates a more gas-like behavior of fluid, the question of whether or not conventional techniques will predict the heat-transfer coefficient at high pressure must be resolved. While some data at 1200 psia are available (refs. 1 and 2), these are limited to specific flows and geometries associated with the requirements of a particular propulsor. Thus the primary objective of this report will be to present the preliminary results from more general hydrogen heat-transfer data taken in the 1000 to 2500 psia regime.

The data presented herein have been taken in uniformly joule-heated, straight, vertical, smooth tubes with an approach-length-to-diameter ratio of at least 35. While this type of test cannot entirely simulate the conditions encountered in an actual propulsion device, it serves as a basis of comparison or as a reference to gage other real effects such as curvature (ref. 3 and a private communication with W. R. Thompson and E. L. Geery of Aerojet General Corporation), fluid acceleration, and asymmetric heating. The heat-transfer data of this report were taken over the following nominal range of conditions:

Heat flux, Btu/(in.^{2})(sec)	up to 10
Pressure, psia	1000 to 2500
Bulk temperature, $^{\circ}$R	60 to 200
Wall-to-bulk temperature ratio	1.5 to 11
Surface temperature, $^{\circ}$R	150 to 1200
Mass flow rate, lb mass/sec	0.05 to 0.4
Mass velocity, lb mass/(in.^{2})(sec)	0.4 to 12
Tube diameter, in.	0.211 to 0.438
Mach number	up to 0.25
Film Reynolds number	10^5 to 4×10^6

Representative data are presented in appendix B

Gaseous hydrogen data (near ambient temperature) were taken to provide both heat-transfer information at high pressures and a check on the precision of the experimental system. Observations and discussion on the

effect of oscillations on heat-transfer coefficients are presented in appendix A.

SYMBOLS

A local surface area, in.^{2}

c_p specific heat, Btu/(lb mass)($^\circ$R)

d diameter of tube, ft or in.

H enthalpy, Btu/lb mass

h local heat-transfer coefficient, Btu/(in.^{2})(sec)($^\circ$R)

k thermal conductivity, Btu/(ft)(sec)($^\circ$R)

k_M material thermal conductivity, Btu/(ft)(hr)($^\circ$R)

L length of test section, in.

Nu Nusselt number, $Nu = 144\ hd/k$

Pr Prandtl number $Pr = c_p\mu/k$

p pressure, psia

Q total heat input, Btu/sec

q local heat flux, Btu/(in.^{2})(sec)

Re Reynolds number, $Re = ud/\nu$

T absolute temperature, $^\circ$R

u bulk velocity, ft/sec

$\dot{W}$ mass flow rate, lb mass/sec

μ viscosity, lb mass/(ft)(sec)

ν kinematic viscosity evaluated at reference conditions, ft^2/sec

Subscripts:

b bulk

exp experimental

f evaluate properties at film conditions, $T_f = (T_w + T_b)/2$

i internal or wall

o external

w wall

APPARATUS AND PROCEDURE

Test Installation

The test installation (fig. 1) consisted of a system wherein high-pressure cryogenic hydrogen, pressurized by gaseous hydrogen, flowed vertically upward through the electrically heated test section and discharged to the atmosphere. The installation was similar to that described in reference 4, but the apparatus was modified and reinforced for operation at pressures up to 3000 psia.

The high-pressure hydrogen gas was produced from high-purity cylinder gas compressed by a two-stage reciprocating compressor. This gas pressurized liquid hydrogen in the 14-cubic-foot vacuum-jacketed Dewar and forced the fluid up through a dip tube to the test section. The dip tube contained two Venturi flowmeters. The entrance Venturi was for flow measurements; the second Venturi was coupled to the flow-control valve by a closed electronic-hydraulic loop for preset control of mass flow rate.

Downstream of the test section, a back-pressure valve regulated test section pressure independently of flow rate. This valve was also operated by an electronic-hydraulic system with an open-loop manual control. In the exhaust piping, the hydrogen discharge passed through a steam-heated heat exchanger and then through a sharp-edged orifice for additional verification of flow rate.

At the entrance to the test section, a short electrically heated section was used to preheat the high-pressure hydrogen, thus allowing operation at bulk temperatures near 200° R.

Test Section

A schematic of the Inconel-600 heat-transfer test sections is shown in figure 2. The test sections were heated resistively to generate power uniformly by a 40-volt-maximum, saturable-reactor-regulated, 150-kilowatt direct-current power supply. Electrical connections to the test sections were made by heavy copper flanges brazed to the test section. The test sections were electrically isolated from the adjacent piping and were enclosed within a vacuum jacket to minimize heat losses or gains.

Instrumentation

Instrumentation locations on the test-section surface are shown in figure 2. Surface thermocouples were Chromel-Alumel referenced to a melting ice bath. Two methods of attachment were used: spot-welding the junction directly to the tube surface, and cementing the junction with a thin layer of ceramic cement. The table with figure 2 indicates the type of attachment used at each axial position. Three couples equispaced circumferentially were used at the spot-welded stations. Agreement between the two types of attachment was generally good, although there is some evidence that the cemented thermocouples are less accurate at low temperatures.

Pressures were measured with static tubes attached to strain-gage transducers. Voltage drop was measured across the test-section electrical-connecting flanges, and current was measured by a millivolt-output shunt installed near the power supply. Power was also independently metered by an electronic wattmeter connected across the voltage taps and to a second current shunt. Because the power supply output had appreciable ripple and some rectifier distortion, an initial calibration of all direct-current instrumentation was made by using thermocouple-type meters which properly averaged the waveform.

Bulk temperatures were measured in baffled mixing chambers at the entrance and exit to the test section by using both platinum- and carbon-resistance thermometers. Flow rates were determined from the indication of differential-pressure transducers across the dip-tube Venturi and exhaust-pipe orifice meters. Piezoelectric accelerometers were mounted on insulating blocks on the copper electrical flanges to measure test-section oscillations (see fig. 1).

All measured variables were conditioned into the form of millivolt signals. These signals were recorded on tape by an automatic voltage digitizing system, and were immediately available as inputs to a high-speed computing program and for a raw data write-back on an electric typewriter. During a test run, all the control variables were also monitored on conventional self-balancing potentiometers and on a multichannel oscillograph. This was done for continuous monitoring to assure steady-state operation and as an independent backup to the data recording system.

Procedure

For each test section, runs were made over a range of flow rates, pressures, and power inputs at low inlet bulk temperatures. A limited number of runs were taken at increased inlet bulk temperatures by using the electrically heated preheater. Each of these parameters could be varied independently over a wide range.

Data reduction. - At each station, several readings of each thermocouple were averaged to give the outside surface temperature. At the spot-welded stations the outside wall temperatures were taken to be the average of the three circumferential thermocouples. The inside surface temperature was computed from the test section geometry, conductivity, and heat flux by the following relation:

$$\int_{T_{ref}}^{T_i} k_M \, dT = \int_{T_{ref}}^{T_o} k_M \, dT - 43200(Q)\left[\frac{d_o^2 \ln\left(\frac{d_o}{d_i}\right) - \frac{d_o^2 - d_i^2}{2}}{2\pi L\left(d_o^2 - d_i^2\right)}\right] \tag{1}$$

Bulk hydrogen temperatures were computed by using the measured inlet-mixing-chamber temperature, increments of heat input, and hydrogen enthalpy. Heat inputs were corrected for the variation in the Inconel wall electrical resistivity, even though the temperature variation was small and the assumption of constant resistivity is a reasonable one. Hydrogen properties were calculated by subroutine STATE (ref. 5). Heat-transfer coefficients were computed as local values according to the usual definition:

$$h_{exp} = \frac{Q}{A(T_i - T_b)} \tag{2}$$

where Q is the incremental heat input over the local surface area A, and T_i and T_b are the corresponding computed inside wall and bulk temperatures. For correlation, values of the standard dimensionless groups, the Nusselt, Prandtl, and Reynolds numbers, were calculated at film conditions, the arithmetic mean between wall and bulk temperatures.

Accuracy of measurements. - Precision of measurement was improved by duplicate sets of instrumentation in most cases. It was felt that surface temperatures could be considered accurate to ±5 percent. Bulk temperatures were measured by both carbon- and platinum-resistance thermometers with a reasonable accuracy of 1 to 3 percent. Pressure and flow measurements were also duplicated; flow was measured through both the inlet Venturi and the exit orifice, and pressure was measured by both static and differential transducers. Accuracy in these cases was held to within ±3 percent.

Electrical power input measurements were duplicated by the wattmeter and independent ammeter and voltmeter readings; accuracy was to about ±5 percent. Power input was checked against the enthalpy-rate increase of the hydrogen, which was computed from the flow rate, bulk inlet- and outlet-temperatures, and thermodynamic properties. The resulting heat balance

$$\text{Heat balance} = \frac{Q - \dot{W}(H_{out} - H_{in})}{Q} \tag{3}$$

showed agreement with a discrepancy generally less than 8 percent. No corrections were made in the recorded surface temperatures for heat losses, and the last station, most subject to conduction error, was not included in the correlation.

RESULTS AND DISCUSSION

Selected data, characteristic of the principal parameters covered in this report, are presented in appendix B. Figures 3 to 6 represent the correlation of local data, but exclude the data with some entrance effects and end losses. More data in these pressure ranges can be made available upon request.

Correlation of 0.211-Inch-Diameter Test-Section Data

The data for the 0.211-inch-inside-diameter, 18-inch-long test section, A-5, neglecting the entrance and end sections are shown in figure 3. While these data are somewhat limited, they are adequately represented by the usual Nusselt-film correlation:

$$Nu_f = CRe_f^p Pr_f^{0.4} \tag{4}$$

where $C = 0.021$ and $p = 0.8$. However, the data are more accurately correlated by changing C and p:

$$Nu_f = 0.0072 \; Re_f^{0.865} Pr_f^{0.4} \tag{5}$$

The data for a second 0.211-inch-diameter test section, A-6, are shown in figure 4. This test section had a center flange to give heated lengths of 8 inches, 10 inches, or a combination of 8 and 10 inches (see fig. 2); the 8-inch length is designated as A-6B and the 10-inch length as A-6A. The 8-inch test section was utilized to give high heat fluxes (up to 10 Btu/(in.^{2})(sec)). The 8 and 10 inch combination was utilized to obtain a higher Mach number (up to 0.25) along with high heat fluxes to yield some indication of the validity of extrapolating a correlation to higher heat flux and Mach number conditions. Notwithstanding the short L/d, most of these data (shown in fig. 4) follow the Nusselt-film correlation (eq. (4)). These data can be more accurately represented by a change in C and p in equation (4), or

$$Nu_f = 0.0105 \; Re_f^{0.83} Pr_f^{0.4} \tag{6}$$

Even though the use of equations (5) and (6) would yield a more accurate representation of the data trends evidenced in figures 3 and 4, it is apparent that the Nusselt-film correlation (eq. (4)) is well within ±20 percent of either equations (5) or (6) and would satisfactorily predict heat transfer over the range of Reynolds number indicated on the figures.

Correlation of 0.315-Inch-Diameter Test-Section Data

Figure 5 depicts the character of the data obtained with the 0.3035-inch-inside-diameter, 18-inch-long test section, A-4. While the majority of the data follow the standard correlation (eq. (4)), some of the data that deviate significantly lie above the correlating line, which indicates either an in-

crease in the experimental deviation of the data or a change in the character of the heat-transfer mechanism. As there is little reason for an increased experimental deviation in the data, it must be assumed that the character of the heat transport has been altered. Perhaps such phenomena as near-critical and extended length-to-diameter effects or oscillations affected the data. The combined L/d and near-critical effects have not been resolved and will not be discussed herein. The observed oscillations, whose effects will be discussed in conjunction with the 0.438-inch-diameter test section, were small for this test section.

A best line through the data of figure 5 indicates these data to be more accurately described by a different C and p:

$$Nu_f = 0.011\ Re_f^{0.85} Pr_f^{0.4} \tag{7}$$

When equations (4) and (7) are compared over the data regime depicted on figure 5, there is a maximum divergence in their mean line prediction of ±10 percent.

Correlation of 0.438-Inch-Diameter Test-Section Data

Considerable difficulty was experienced when correlating the heat-transfer data for the 0.438-inch-diameter test section at lower pressures approaching the critical point. Similar difficulties were encountered in correlating the data taken at high pressures in this investigation. It was discovered, however, that runs with unpredictable heat transfer were accompanied by audible emissions from the test section; thus, a judiciously operated program to exclude these problem regimes was undertaken. Various combinations of operating parameters could yield nonoscillatory conditions, a fact further verified by the readings of accelerometers.

The results at controlled nonoscillatory conditions for the 0.438-inch-inside-diameter, 15-inch-long test section, A-7, are presented in figure 6. It can be seen from this figure and appendix B that the data, while apparently L/d dependent over most of the heated length, follow the standard Nusselt-film correlation (eq. (4)), although not as well as the smaller diameter test sections.

Again the average data appear to be more accurately described by a change in the constant C and exponent p:

$$Nu_f = 0.006\ Re_f^{0.9} Pr_f^{0.4} \tag{8}$$

In this case, at high Re_f values, the departure from equation (4) is over 20 percent. Similar changes in the Reynolds number exponent have been noted by several investigators (e.g., ref. 6). However, for most of the data of figure 6 the Nusselt-film correlation is still quite good for predicting heat transfer.

Observed System Oscillations

The character of the oscillations encountered in the 0.438-inch-diameter test section were detected by piezoelectric accelerometers mounted on the test section (see fig. 2). The accelerometers were capable of detecting both vertical and lateral oscillations. Vertical oscillations (800 to 1000 cps) appeared to be system dependent and to have little effect on the data; lateral oscillations (4500 to 8000 cps), however, significantly increased the heat-transfer rates over that predicted by the Nusselt-film correlation. These lateral oscillations were not observed in the smaller tubes probably due to the increased inertial damping rates in the smaller tubes. It also seems likely that previous data at lower pressures in tubes similar to the 0.438-inch-diameter tube could have been affected by oscillations. Oscillations at higher pressures are discussed more fully in appendix A.

Discussion of Heat Transfer at High Pressures

For the entire pressure range of 1000 to 2500 psia included in figures 3 to 6, the data follow the standard Nusselt-film correlation (eq. (4)). The effects of the entrance region (L/d) still require further study. The effects of T_w/T_b and Mach number as well as tube diameter do not appear to influence the standard Nusselt-film correlation, although this observation should be checked over a wider range of the variables investigated herein.

Gaseous hydrogen was used to test higher bulk temperatures and to establish the validity of the heat-transfer system. The data of the 0.438-inch-diameter test section, A-7, are plotted in figure 7. In general the gaseous hydrogen data follow the Nusselt-film correlation. From the figure the data appear to have large L/d effects; a characteristic that is probably amplified at the lower bulk temperatures.

Pressure Drop

The pressure drop data across the test section were not considered sufficiently accurate to obtain valid friction factors.

SUMMARY OF RESULTS

In general, it appears that for the data regimes covered by this report the Nusselt-film correlation

$$Nu_f = 0.021\ Re_f^{0.8} Pr_f^{0.4}$$

will yield sufficiently accurate heat-transfer predictions provided entrance, end effects, and high-frequency flow oscillations are obviated. The data taken and correlated by the previous relation covered the following nominal range of conditions:

Heat flux, Btu/(in.^{2})(sec)	up to 10
Pressure, psia	1000 to 2500
Bulk temperature, $^{\circ}$R	60 to 200
Wall-to-bulk temperature ratios	1.5 to 11
Surface temperatures, $^{\circ}$R	150 to 1200
Mass flow rate, lb mass/sec	0.05 to 0.4
Tube diameter, in.	0.211 to 0.438
Mach number	up to 0.25
Film Reynolds number	10^5 to 4×10^6

The data for each test section are more accurately described by modifications of the Reynolds number exponent and the constant coefficient in the Nusselt-film correlation. Since it was not possible to extrapolate the experiment to higher and lower Reynolds numbers to confirm these coefficient and exponent differences for each geometry, it is recommended that the standard Nusselt-film correlation be applied to all tube geometries over the range investigated and to cooling passage designs.

Data taken while the test section was in a high frequency lateral oscillation (4500 to 8000 cps) indicated a significant increase in heat transfer over that predicted from the Nusselt-film correlation. These oscillations appear to be quite dependent on the damping rate established by flow velocity, since they were prevalent mainly in the low-velocity, 0.438-inch-diameter test section.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, June 7, 1965.

APPENDIX A

SYSTEM OSCILLATIONS

Only a limited amount of heat-transfer data were influenced by oscillations, and these data were excluded from consideration in formulating the recommended correlation. Nevertheless, a discussion of the oscillatory experience will be presented in this appendix for those readers interested primarily in this phenomenon. Also, this discussion is intended to emphasize the importance of detecting the potential presence of fluid oscillations in a heat-transfer experiment.

The locations of the lateral and vertical accelerometers used in these tests to determine system oscillations are indicated in figure 1. In the following discussion, the vertical and lateral oscillation experience will be treated separately.

Vertical Oscillations

During the early phases of operation where the 0.315-inch-diameter test section A-4 was used, the accelerometers indicated very little evidence of flow instability of sufficient magnitude to affect the heat-transfer data. Consequently, system oscillations were not carefully monitored until "screaming" (1000 cps at 10:1 gain) was heard during initial tests with the 0.438-inch-diameter test section. At first it was believed that the screaming was affected by heating. However, subsequent investigation indicated the noise could occur at low amplitude even without heating or flow, but it occurred most frequently at higher amplitudes during startup conditions. This noise, monitored on the vertical accelerometer, appeared to arise from the hydraulic control system and was amplified when flow control was required. Several runs were made with the characteristic 800 to 1000 cycles per second noise quite evident on the vertical accelerometer, while the noise recorded on the lateral accelerometer was about 750 cycles per second. The heat-transfer data for these runs did not appear to be greatly affected by these oscillations, as illustrated in figure 8. The 0.438-inch-diameter test-section data reported herein were carefully monitored, and the high amplitude 800 to 1000 cycles per second vertical oscillations have been eliminated.

These oscillations, although probably present during the testing of the other tubes, did not have a detrimental effect on the data. In the smaller diameter tubes, the damping rate is usually very much higher (velocities are from 1 to 15 times those of the 0.438-in.-diam. tube); hence, a suppression of the 800 to 1000 cycles per second oscillations would be expected.

Lateral Oscillations

Higher frequency audible oscillations (4500 to 8000 cps) were noted on the lateral accelerometer only during certain runs. These oscillations substantially augmented the heat-transfer process as indicated in figure 9. Similar

trends in the gaseous hydrogen data regime were encountered in reference 7, where the system remained quasi-stable.[1] Data with known high frequency lateral oscillations are not included in appendix B.

A characteristic of most near-critical hydrogen heat-transfer data (200 to 800 psia, ref. 4) is its quasi-stable nature. The low frequency oscillations (the order of 1 cps) encountered at low pressure (200 to 800 psia) were not prevalent above 1000 pounds per square inch absolute. These low frequency oscillations at sub- and supercritical pressure have been studied in reference 8.

A more complete description of the oscillation mechanism and its influence on heat transfer requires more elaborate instrumentation and was not undertaken in this investigation.

[1]By quasi-stable it is meant that once the power, flow, and pressure have been set, they maintain their settings within a limited tolerance. To be sure, disturbances grow and decay, but their magnitudes are bounded and time-averaged measurements are reproducible.

APPENDIX B

TABULATED DATA

Table I is a representative set of the local experimental data. The points that are starred are ones for which the outside wall temperature at that station was known to be in error. The following is a list of the symbols used in the table:

H	heat-transfer coefficient, Btu/(in.^{2})(sec)($^\circ$R)
HEX/HC	experimental to calculated (eq. (4)) heat-transfer coefficient ratio
HT.BAL	heat balance, eq. (3)
HT.-FLUX	average heat flux, Btu/(in.^{2})(sec)
I.D.	inside diameter, in.
MACH	Mach number
P-IN	inlet pressure, psia
P-OUT	exit pressure, psia
RE-FILM	Reynolds number, film = ud/ν_f
RHOB	bulk density, lb mass/ft^3
RUN	reference number
TB	bulk temperature, $^\circ$R
TI	inside wall temperature, $^\circ$R
TI/TB	wall to bulk temperature ratio
TO	outside wall temperature, $^\circ$R
T.S.	test section number (for test section specifications see fig. 2)
VELOC	bulk velocity, ft/sec
WT.-FLOW	mass flow rate, lb mass/sec
X/D	axial location to diameter ratio

TABLE I. - HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
77	A-4	0.3148	1094.	1089.	0.220	1.02	0.04	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	59.	4.17	98.	256.	166.	2.79	0.00949	1.21	1.77E 06
7.9	61.	4.12	99.	265.	175.	2.88	0.00882	1.18	1.70E 06
14.3	64.	4.01	102.	298.	209.	3.27	0.00696	1.08	1.43E 06
17.5	65.	3.95	103.	282.	192.	2.95	0.00793	1.14	1.58E 06
20.6	67.	3.89	105.	294.	205.	3.08	0.00731	1.10	1.48E 06
27.0	69.	3.78	108.	321.	233.	3.37	0.00617	1.01	1.29E 06
30.2	71.	3.73	109.	290.	201.	2.84	0.00775	1.13	1.55E 06
33.4	72.	3.67	111.	*300.	212.	2.94	0.00723	1.09	1.47E 06
39.7	74.	3.56	115.	292.	203.	2.73	0.00787	1.13	1.57E 06
42.9	76.	3.51	116.	289.	200.	2.64	0.00812	1.15	1.61E 06
46.1	77.	3.45	118.	299.	211.	2.74	0.00755	1.10	1.53E 06
52.4	79.	3.37	121.	*300.	211.	2.69	0.00762	1.10	1.55E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
78	A-4	0.3148	1043.	1040.	0.138	1.03	0.03	-0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	65.	3.93	65.	328.	240.	3.69	0.00581	1.49	7.50E 05
7.9	67.	3.84	67.	344.	256.	3.82	0.00537	1.41	6.98E 05
14.3	71.	3.66	70.	363.	276.	3.88	0.00497	1.32	6.53E 05
17.5	73.	3.57	72.	381.	295.	4.03	0.00459	1.24	5.10E 05
20.6	75.	3.48	74.	380.	294.	3.91	0.00455	1.24	6.24E 05
27.0	79.	3.30	78.	387.	302.	3.82	0.00457	1.18	6.25E 05
30.2	81.	3.21	80.	*400.	315.	3.90	0.00435	1.13	6.03E 05
33.4	82.	3.13	82.	397.	312.	3.78	0.00445	1.13	6.23E 05
39.7	86.	2.96	87.	416.	331.	3.85	0.00415	1.04	6.01E 05
42.9	88.	2.88	89.	426.	341.	3.89	0.00404	1.00	5.91E 05
45.1	89.	2.80	91.	432.	348.	3.89	0.00396	0.97	5.88E 05
52.4	92.	2.69	95.	434.	350.	3.80	0.00397	0.95	6.04E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
80	A-4	0.3148	1131.	1121.	0.213	2.69	0.04	0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	62.	4.09	96.	651.	445.	7.16	0.00696	1.67	5.23E 05
7.9	66.	3.94	100.	714.	515.	7.79	0.00597	1.53	4.37E 05
14.3	73.	3.64	108.	805.	615.	8.37	0.00498	1.37	3.61E 05
17.5	77.	3.49	113.	858.	673.	8.76	0.00454	1.30	3.28E 05
20.6	80.	3.34	118.	834.	647.	8.07	0.00476	1.29	3.59E 05
27.0	86.	3.06	129.	875.	692.	8.00	0.00447	1.20	3.52E 05
30.2	90.	2.92	135.	929.	751.	8.38	0.00411	1.16	3.25E 05
33.4	93.	2.79	141.	904.	724.	7.81	0.00430	1.13	3.56E 05
39.7	99.	2.55	154.	911.	731.	7.40	0.00429	1.07	3.80E 05
42.9	102.	2.43	162.	926.	748.	7.33	0.00421	1.04	3.83E 05
46.1	105.	2.33	169.	891.	710.	6.76	0.00448	1.02	4.28E 05
52.4	110.	2.18	181.	803.	613.	5.58	0.00536	1.02	5.55E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
85	A-4	0.3148	1361.	1357.	0.128	1.89	0.02	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	67.	4.06	58.	793.	662.	9.88	0.00316	1.29	2.10E 05
7.9	72.	3.90	61.	632.	489.	6.83	0.00445	1.42	3.30E 05
14.3	80.	3.58	66.	706.	569.	7.10	0.00383	1.28	2.86E 05
17.5	84.	3.42	69.	767.	634.	7.54	0.00342	1.20	2.55E 05
20.6	88.	3.27	73.	733.	597.	6.79	0.00358	1.20	2.87E 05
27.0	96.	2.99	80.	780.	648.	6.77	0.00341	1.10	2.77E 05
30.2	99.	2.85	83.	850.	722.	7.27	0.00303	1.05	2.47E 05
33.4	103.	2.72	87.	831.	702.	6.80	0.00315	1.03	2.67E 05
39.7	111.	2.49	95.	861.	734.	6.63	0.00303	0.99	2.71E 05
42.9	114.	2.38	100.	882.	757.	6.61	0.00295	0.95	2.70E 05
45.1	118.	2.28	104.	845.	717.	6.07	0.00315	0.94	3.01E 05
52.4	124.	2.14	111.	793.	661.	5.34	0.00350	0.92	3.53E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
86	A-4	0.3148	1346.	1343.	0.096	1.91	0.02	0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	73.	3.83	47.	*900.	776.	10.59	0.00271	1.57	1.30E 05
7.9	79.	3.61	49.	781.	648.	8.21	0.00331	1.55	1.76E 05
14.3	90.	3.20	56.	893.	768.	8.58	0.00280	1.43	1.53E 05
17.5	95.	3.00	59.	972.	850.	8.97	0.00253	1.34	1.40E 05
20.6	100.	2.82	63.	951.	828.	8.30	0.00262	1.30	1.53E 05
27.0	110.	2.49	71.	958.	835.	7.60	0.00263	1.20	1.68E 05
30.2	115.	2.35	76.	997.	875.	7.61	0.00252	1.13	1.66E 05
33.4	120.	2.22	80.	972.	849.	7.08	0.00262	1.11	1.81E 05
39.7	130.	1.99	90.	955.	833.	6.39	0.00272	1.05	2.05E 05
42.9	136.	1.89	94.	947.	824.	6.07	0.00277	1.02	2.17E 05
46.1	141.	1.79	99.	931.	808.	5.73	0.00285	1.00	2.32E 05
52.4	149.	1.67	106.	863.	736.	4.94	0.00323	1.01	2.78E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
87	A-4	0.3148	1490.	1486.	0.139	1.97	0.02	0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	64.	4.25	61.	*600.	447.	7.03	0.00511	1.43	4.09E 05
7.9	68.	4.09	63.	604.	451.	6.60	0.00512	1.40	4.14E 05
14.3	77.	3.79	68.	678.	531.	6.88	0.00434	1.26	3.50E 05
17.5	81.	3.64	71.	738.	596.	7.34	0.00384	1.18	3.08E 05
20.6	85.	3.50	74.	682.	535.	6.28	0.00438	1.21	3.67E 05
27.0	93.	3.22	80.	721.	577.	6.21	0.00408	1.12	3.54E 05
30.2	97.	3.09	83.	819.	682.	7.05	0.00339	1.03	2.91E 05
33.4	101.	2.96	87.	799.	661.	6.58	0.00354	1.01	3.15E 05
39.7	108.	2.72	95.	850.	716.	6.62	0.00328	0.96	3.03E 05
42.9	112.	2.61	98.	881.	749.	6.70	0.00313	0.94	2.94E 05
45.1	115.	2.51	102.	841.	706.	6.11	0.00337	0.92	3.30E 05
52.4	121.	2.37	109.	815.	678.	5.60	0.00357	0.90	3.64E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
93	A-4	0.3148	789.	785.	0.054	0.97	0.06	-0.13	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	306.	0.46	217.	584.	510.	1.66	0.00472	1.17	3.95E 05
7.9	311.	0.46	220.	607.	534.	1.72	0.00431	1.10	3.78E 05
14.3	320.	0.44	226.	532.	456.	1.43	0.00702	1.60	4.50E 05
17.5	324.	0.44	229.	641.	569.	1.76	0.00394	1.03	3.59E 05
20.6	328.	0.43	232.	622.	549.	1.67	0.00436	1.11	3.74E 05
27.0	337.	0.42	239.	665.	594.	1.76	0.00376	0.98	3.49E 05
30.2	341.	0.41	242.	664.	592.	1.74	0.00385	1.00	3.52E 05
33.4	346.	0.41	245.	639.	567.	1.64	0.00436	1.10	3.70E 05
39.7	354.	0.40	251.	679.	608.	1.72	0.00380	0.98	3.47E 05
42.9	359.	0.39	254.	660.	588.	1.64	0.00421	1.06	3.61E 05
46.1	363.	0.39	258.	*569.	494.	1.36	0.00734	1.58	4.31E 05
52.4	370.	0.38	263.	692.	622.	1.68	0.00384	0.98	3.45E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
95	A-4	0.3148	2095.	2091.	0.128	1.89	0.02	-0.08	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	74.	4.24	56.	*500.	347.	4.72	0.00683	1.43	6.34E 05
7.9	78.	4.10	58.	587.	439.	5.50	0.00521	1.19	4.92E 05
14.3	88.	3.83	62.	634.	489.	5.57	0.00470	1.09	4.50E 05
17.5	92.	3.70	64.	647.	503.	5.45	0.00450	1.06	4.45E 05
20.6	97.	3.58	66.	645.	501.	5.18	0.00457	1.05	4.58E 05
27.0	105.	3.34	71.	672.	530.	5.03	0.00445	1.00	4.48E 05
30.2	110.	3.22	73.	686.	545.	4.97	0.00435	0.97	4.44E 05
33.4	114.	3.12	76.	691.	551.	4.84	0.00433	0.95	4.49E 05
39.7	122.	2.92	81.	716.	578.	4.73	0.00416	0.90	4.44E 05
42.9	126.	2.83	84.	745.	608.	4.82	0.00395	0.86	4.27E 05
46.1	130.	2.74	86.	738.	601.	4.61	0.00404	0.86	4.43E 05
52.4	136.	2.61	91.	745.	608.	4.45	0.00403	0.84	4.52E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
96	A-4	0.3148	1736.	1731.	0.128	2.57	0.02	-0.10	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	73.	4.09	58.	*900.	729.	10.03	0.00393	1.45	2.21E 05
7.9	79.	3.89	61.	845.	669.	8.46	0.00435	1.44	2.58E 05
14.3	91.	3.50	68.	972.	805.	8.84	0.00363	1.35	2.18E 05
17.5	97.	3.32	71.	1050.	883.	9.13	0.00331	1.27	2.00E 05
20.6	102.	3.14	75.	1006.	839.	8.19	0.00352	1.26	2.25E 05
27.0	113.	2.83	84.	1048.	881.	7.77	0.00339	1.15	2.29E 05
30.2	119.	2.68	88.	1136.	969.	8.15	0.00308	1.09	2.09E 05
33.4	124.	2.55	93.	1099.	932.	7.50	0.00323	1.07	2.30E 05
39.7	135.	2.32	102.	1107.	940.	6.94	0.00325	1.01	2.47E 05
42.9	141.	2.21	107.	1116.	948.	6.73	0.00324	0.98	2.53E 05
46.1	146.	2.11	112.	1075.	908.	6.20	0.00342	0.97	2.79E 05
52.4	154.	1.99	119.	1002.	835.	5.41	0.00381	0.98	3.28E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
97	A-4	0.3148	1592.	1589.	0.125	0.97	0.02	-0.06	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	64.	4.28	54.	298.	214.	3.32	0.00641	1.29	8.88E 05
7.9	67.	4.19	55.	304.	220.	3.29	0.00524	1.27	8.75E 05
14.3	72.	4.03	57.	308.	224.	3.11	0.00630	1.27	8.80E 05
17.5	74.	3.95	59.	335.	252.	3.39	0.00541	1.15	7.97E 05
20.6	77.	3.87	60.	318.	234.	3.05	0.00609	1.23	8.64E 05
27.0	81.	3.72	62.	340.	258.	3.17	0.00544	1.13	8.04E 05
30.2	84.	3.64	64.	348.	266.	3.18	0.00528	1.10	7.89E 05
33.4	86.	3.56	65.	339.	256.	2.99	0.00563	1.14	8.29E 05
39.7	90.	3.41	68.	358.	276.	3.06	0.00517	1.05	7.88E 05
42.9	92.	3.34	69.	356.	274.	2.97	0.00529	1.06	8.05E 05
46.1	94.	3.27	71.	373.	291.	3.09	0.00489	0.99	7.64E 05
52.4	97.	3.16	73.	374.	292.	3.00	0.00495	0.98	7.78E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
98	A-4	0.3148	1601.	1597.	0.201	0.99	0.03	-0.07	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	59.	4.44	84.	249.	160.	2.70	0.00980	1.17	1.57E 06
7.9	61.	4.38	85.	251.	162.	2.66	0.00971	1.16	1.59E 06
14.3	64.	4.28	87.	268.	180.	2.81	0.00848	1.05	1.58E 06
17.5	66.	4.23	88.	270.	182.	2.76	0.00848	1.05	1.58E 06
20.6	68.	4.18	89.	273.	185.	2.75	0.00833	1.04	1.58E 06
27.0	71.	4.07	91.	280.	192.	2.72	0.00811	1.02	1.58E 06
30.2	72.	4.02	93.	275.	187.	2.59	0.00857	1.06	1.61E 06
33.4	74.	3.97	94.	271.	183.	2.47	0.00905	1.10	1.65E 06
39.7	77.	3.87	96.	280.	193.	2.50	0.00851	1.05	1.63E 06
42.9	78.	3.82	98.	272.	184.	2.35	0.00933	1.12	1.69E 06
46.1	80.	3.77	99.	287.	200.	2.51	0.00819	1.03	1.61E 06
52.4	82.	3.69	101.	284.	197.	2.39	0.00861	1.06	1.65E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
100	A-4	0.3148	1578.	1574.	0.124	1.88	0.02	-0.08	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	69.	4.11	56.	*600.	455.	6.58	0.00481	1.40	3.77E 05
7.9	74.	3.96	58.	622.	479.	6.47	0.00459	1.34	3.61E 05
14.3	83.	3.65	63.	694.	555.	6.69	0.00395	1.21	3.14E 05
17.5	87.	3.50	65.	743.	608.	6.96	0.00359	1.14	2.87E 05
20.6	92.	3.35	68.	711.	574.	6.26	0.00388	1.15	3.21E 05
27.0	100.	3.07	74.	756.	622.	6.23	0.00359	1.06	3.08E 05
30.2	104.	2.94	78.	817.	688.	6.62	0.00322	1.00	2.78E 05
33.4	108.	2.82	81.	801.	670.	6.21	0.00334	0.99	2.98E 05
39.7	116.	2.60	88.	853.	726.	6.26	0.00309	0.94	2.87E 05
42.9	120.	2.49	92.	893.	769.	6.41	0.00291	0.91	2.75E 05
46.1	124.	2.40	95.	947.	720.	5.80	0.00317	0.91	3.10E 05
52.4	130.	2.26	101.	841.	713.	5.49	0.00323	0.88	3.29E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
101	A-4	0.3148	1513.	1506.	0.200	1.88	0.03	-0.05

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	63.	4.29	86.	*500.	347.	5.54	0.00656	1.21	8.23E 05
7.9	66.	4.19	89.	504.	351.	5.33	0.00655	1.19	8.22E 05
14.3	72.	3.99	93.	541.	390.	5.42	0.00589	1.09	7.41E 05
17.5	75.	3.89	95.	518.	366.	4.89	0.00643	1.14	8.15E 05
20.6	78.	3.79	98.	552.	402.	5.18	0.00578	1.05	7.35E 05
27.0	83.	3.59	103.	608.	461.	5.55	0.00498	0.93	6.38E 05
30.2	86.	3.50	106.	546.	395.	4.61	0.00606	1.04	7.92E 05
33.4	88.	3.40	109.	562.	412.	4.67	0.00579	0.99	7.65E 05
39.7	93.	3.22	115.	565.	415.	4.45	0.00583	0.96	7.89E 05
42.9	96.	3.14	118.	579.	431.	4.49	0.00561	0.92	7.69E 05
46.1	98.	3.05	122.	590.	443.	4.50	0.00546	0.89	7.57E 05
52.4	102.	2.93	127.	579.	430.	4.21	0.00572	0.90	8.09E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
110	A-4	0.3148	1540.	1536.	0.097	1.89	0.02	-0.16

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	101.	3.00	60.	*700.	562.	5.57	0.00407	1.36	2.77E 05
7.9	106.	2.84	63.	665.	524.	4.94	0.00447	1.38	3.16E 05
14.3	116.	2.55	70.	753.	618.	5.32	0.00375	1.20	2.77E 05
17.5	121.	2.42	74.	844.	716.	5.90	0.00318	1.13	2.38E 05
20.6	126.	2.30	78.	747.	612.	4.85	0.00387	1.15	3.04E 05
27.0	137.	2.09	86.	803.	672.	4.91	0.00353	1.06	2.92E 05
30.2	142.	1.99	90.	919.	796.	5.60	0.00291	0.98	2.42E 05
33.4	147.	1.91	94.	863.	737.	5.00	0.00322	1.00	2.78E 05
39.7	158.	1.76	102.	949.	826.	5.25	0.00285	0.91	2.54E 05
42.9	163.	1.69	106.	1031.	909.	5.58	0.00257	0.85	2.31E 05
46.1	168.	1.63	110.	1026.	903.	5.37	0.00251	0.84	2.39E 05
52.4	176.	1.54	116.	940.	817.	4.64	0.00297	0.86	2.85E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
113	A-4	0.3148	1112.	1107.	0.134	0.95	0.04	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	91.	2.85	87.	343.	261.	2.88	0.00556	1.19	8.33E 05
7.9	93.	2.78	89.	356.	275.	2.97	0.00519	1.12	7.97E 05
14.3	96.	2.64	94.	349.	268.	2.79	0.00553	1.14	8.54E 05
17.5	98.	2.57	96.	356.	275.	2.82	0.00534	1.09	8.42E 05
20.6	99.	2.51	99.	365.	284.	2.86	0.00514	1.05	8.26E 05
27.0	103.	2.38	104.	374.	294.	2.86	0.00498	0.99	8.24E 05
30.2	104.	2.32	107.	366.	285.	2.73	0.00526	1.02	8.70E 05
33.4	106.	2.27	109.	353.	272.	2.56	0.00571	1.06	9.32E 05
39.7	110.	2.16	115.	372.	292.	2.66	0.00522	0.97	8.93E 05
42.9	111.	2.11	118.	358.	277.	2.49	0.00571	1.02	9.60E 05
46.1	113.	2.06	120.	330.	248.	2.20	0.00699	1.18	1.10E 06
52.4	116.	1.99	125.	378.	297.	2.57	0.00523	0.92	9.23E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
114	A-4	0.3148	1002.	999.	0.084	1.04	0.03	-0.05

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	110.	1.96	79.	421.	336.	3.05	0.00452	1.30	4.77E 05
7.9	113.	1.88	83.	409.	324.	2.86	0.00485	1.33	5.16E 05
14.3	119.	1.74	89.	452.	368.	3.09	0.00412	1.13	4.69E 05
17.5	122.	1.67	93.	483.	400.	3.27	0.00370	1.02	4.36E 05
20.6	126.	1.61	97.	422.	337.	2.69	0.00483	1.21	5.50E 05
27.0	132.	1.50	104.	446.	362.	2.74	0.00446	1.10	5.31E 05
30.2	136.	1.45	107.	*500.	417.	3.08	0.00355	0.93	4.59E 05
33.4	139.	1.40	111.	484.	401.	2.88	0.00392	0.96	4.93E 05
39.7	146.	1.31	118.	510.	428.	2.93	0.00365	0.89	4.76E 05
42.9	149.	1.28	122.	*416.	331.	2.22	0.00552	1.20	6.53E 05
46.1	152.	1.24	125.	506.	423.	2.77	0.00380	0.89	5.01E 05
52.4	158.	1.19	130.	519.	436.	2.77	0.00369	0.86	4.96E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
116	A-4	0.3148	1042.	1032.	0.210	1.90	0.05	0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	78.	3.34	116.	380.	218.	2.79	0.01348	2.12	1.40E 06
7.9	80.	3.24	120.	427.	268.	3.34	0.01005	1.74	1.11E 06
14.3	84.	3.03	128.	431.	272.	3.22	0.01009	1.68	1.15E 06
17.5	87.	2.93	133.	552.	399.	4.61	0.00609	1.18	7.21E 05
20.6	89.	2.83	137.	515.	360.	4.06	0.00700	1.26	8.46E 05
27.0	93.	2.64	147.	487.	331.	3.56	0.00797	1.31	9.92E 05
30.2	95.	2.55	152.	580.	429.	4.52	0.00571	1.04	7.30E 05
33.4	97.	2.47	158.	445.	287.	2.95	0.00999	1.48	1.25E 06
39.7	101.	2.30	169.	603.	454.	4.47	0.00543	0.95	7.37E 05
42.9	104.	2.23	175.	628.	481.	4.64	0.00508	0.90	7.03E 05
46.1	106.	2.15	181.	532.	378.	3.57	0.00699	1.06	9.84E 05
52.4	109.	2.05	190.	584.	433.	3.97	0.00589	0.92	8.60E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
117	A-4	0.3148	900.	886.	0.209	2.54	0.05	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	77.	3.19	121.	483.	264.	3.43	0.01395	2.68	1.04E 06
7.9	80.	3.04	128.	*600.	391.	4.89	0.00846	1.88	6.43E 05
14.3	86.	2.74	142.	783.	592.	6.92	0.00525	1.40	3.95E 05
17.5	88.	2.60	149.	916.	738.	8.35	0.00414	1.27	3.01E 05
20.6	91.	2.46	158.	841.	656.	7.20	0.00474	1.25	3.74E 05
27.0	97.	2.21	175.	801.	612.	6.33	0.00518	1.20	4.53E 05
30.2	100.	2.09	185.	913.	735.	7.38	0.00423	1.11	3.65E 05
33.4	103.	1.99	195.	844.	660.	6.43	0.00480	1.09	4.46E 05
39.7	109.	1.80	215.	864.	682.	6.27	0.00457	1.02	4.64E 05
42.9	112.	1.72	226.	859.	677.	6.05	0.00474	0.99	4.89E 05
46.1	115.	1.64	236.	852.	669.	5.82	0.00483	0.97	5.16E 05
52.4	120.	1.54	252.	727.	531.	4.43	0.00646	1.06	7.44E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
120	A-4	0.3148	2103.	2100.	0.105	1.01	0.02	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	74.	4.24	46.	354.	270.	3.65	0.00507	1.12	6.75E 05
7.9	77.	4.15	47.	395.	311.	4.05	0.00425	0.98	5.99E 05
14.3	83.	3.98	50.	379.	295.	3.56	0.00459	1.03	6.45E 05
17.5	86.	3.89	51.	386.	302.	3.51	0.00461	1.01	6.39E 05
20.6	89.	3.81	52.	407.	324.	3.64	0.00424	0.94	6.04E 05
27.0	95.	3.65	54.	406.	323.	3.41	0.00437	0.94	6.22E 05
30.2	97.	3.57	55.	398.	315.	3.23	0.00458	0.96	6.46E 05
33.4	100.	3.49	56.	411.	328.	3.28	0.00437	0.91	6.27E 05
39.7	106.	3.34	59.	410.	327.	3.09	0.00451	0.91	6.48E 05
42.9	108.	3.26	60.	412.	329.	3.04	0.00451	0.90	6.52E 05
46.1	111.	3.20	62.	426.	343.	3.09	0.00430	0.86	6.34E 05
52.4	115.	3.10	64.	418.	336.	2.92	0.00452	0.88	6.61E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
121	A-4	0.3148	2087.	2084.	0.139	1.01	0.02	0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	70.	4.34	59.	317.	230.	3.30	0.00621	1.06	9.71E 05
7.9	72.	4.28	60.	326.	240.	3.33	0.00593	1.02	9.55E 05
14.3	77.	4.14	62.	323.	236.	3.07	0.00624	1.04	9.84E 05
17.5	79.	4.08	63.	334.	248.	3.13	0.00592	1.00	9.62E 05
20.6	82.	4.01	64.	360.	275.	3.37	0.00516	0.90	8.93E 05
27.0	86.	3.88	66.	362.	277.	3.22	0.00523	0.90	9.04E 05
30.2	88.	3.81	68.	344.	258.	2.92	0.00589	0.97	9.70E 05
33.4	91.	3.75	69.	356.	270.	2.98	0.00556	0.92	9.42E 05
39.7	95.	3.63	71.	350.	264.	2.79	0.00589	0.95	9.79E 05
42.9	97.	3.57	72.	343.	258.	2.66	0.00621	0.98	1.01E 06
46.1	99.	3.51	74.	360.	275.	2.78	0.00567	0.91	9.65E 05
52.4	102.	3.42	75.	353.	268.	2.62	0.00602	0.94	1.00E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
122	A-4	0.3148	2186.	2181.	0.215	1.01	0.03	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	65.	4.53	88.	274.	185.	2.86	0.00834	0.94	1.54E 06
7.9	66.	4.48	89.	258.	168.	2.54	0.00981	1.07	1.55E 06
14.3	70.	4.39	91.	272.	183.	2.63	0.00883	0.97	1.59E 06
17.5	71.	4.35	92.	277.	188.	2.64	0.00859	0.95	1.60E 06
20.6	73.	4.31	92.	305.	217.	2.99	0.00695	0.80	1.55E 06
27.0	76.	4.22	94.	311.	224.	2.95	0.00680	0.78	1.56E 06
30.2	77.	4.17	95.	284.	196.	2.53	0.00847	0.93	1.65E 06
33.4	79.	4.13	96.	298.	210.	2.66	0.00764	0.85	1.62E 06
39.7	82.	4.05	98.	285.	196.	2.40	0.00876	0.94	1.69E 06
42.9	84.	4.00	99.	283.	194.	2.32	0.00907	0.97	1.71E 06
46.1	85.	3.96	101.	297.	209.	2.45	0.00811	0.88	1.68E 06
52.4	87.	3.90	102.	287.	198.	2.27	0.00906	0.96	1.73E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
123	A-4	0.3148	2242.	2237.	0.139	2.65	0.02	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	74.	4.30	60.	508.	291.	3.95	0.01210	2.16	8.37E 05
7.9	80.	4.13	62.	700.	500.	6.24	0.00534	1.39	4.75E 05
14.3	92.	3.79	68.	743.	547.	5.93	0.00587	1.30	4.49E 05
17.5	98.	3.63	71.	855.	671.	6.83	0.00459	1.16	3.56E 05
20.6	104.	3.48	74.	771.	578.	5.56	0.00554	1.22	4.45E 05
27.0	115.	3.19	81.	807.	618.	5.38	0.00533	1.14	4.35E 05
30.2	120.	3.07	84.	926.	748.	6.21	0.00430	1.08	3.54E 05
33.4	126.	2.94	87.	884.	703.	5.59	0.00467	1.07	3.94E 05
39.7	137.	2.72	95.	974.	799.	5.84	0.00410	0.99	3.56E 05
42.9	142.	2.61	98.	1016.	841.	5.91	0.00389	0.95	3.42E 05
46.1	148.	2.52	102.	996.	821.	5.56	0.00403	0.95	3.64E 05
52.4	155.	2.39	108.	945.	768.	4.95	0.00441	0.96	4.12E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
126	A-4	0.3148	2201.	2199.	0.105	1.88	0.02	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	76.	4.23	46.	485.	331.	4.38	0.00732	1.71	5.61E 05
7.9	82.	4.07	48.	*600.	453.	5.55	0.00508	1.32	4.05E 05
14.3	93.	3.75	52.	646.	502.	5.40	0.00462	1.22	3.76E 05
17.5	98.	3.60	54.	717.	578.	5.88	0.00396	1.11	3.24E 05
20.6	104.	3.46	56.	671.	529.	5.10	0.00445	1.15	3.72E 05
27.0	114.	3.19	61.	704.	564.	4.94	0.00422	1.08	3.65E 05
30.2	119.	3.07	63.	772.	638.	5.35	0.00358	1.00	3.22E 05
33.4	124.	2.95	66.	759.	623.	5.02	0.00381	0.99	3.40E 05
39.7	134.	2.74	71.	813.	682.	5.07	0.00349	0.94	3.23E 05
42.9	139.	2.64	74.	844.	715.	5.12	0.00333	0.92	3.14E 05
46.1	145.	2.54	76.	840.	710.	4.91	0.00338	0.91	3.25E 05
52.4	152.	2.42	80.	824.	694.	4.57	0.00353	0.90	3.47E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
127	A-4	0.3148	2014.	2010.	0.138	1.89	0.02	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	71.	4.28	60.	458.	302.	4.25	0.00812	1.57	7.74E 05
7.9	76.	4.14	62.	600.	452.	5.97	0.00503	1.13	4.98E 05
14.3	84.	3.89	66.	582.	432.	5.12	0.00544	1.15	5.46E 05
17.5	89.	3.76	68.	603.	455.	5.13	0.00517	1.09	5.24E 05
20.6	93.	3.64	70.	600.	451.	4.86	0.00528	1.09	5.41E 05
27.0	101.	3.40	75.	629.	483.	4.78	0.00497	1.02	5.22E 05
30.2	105.	3.29	77.	641.	496.	4.73	0.00485	1.00	5.17E 05
33.4	109.	3.19	80.	649.	504.	4.63	0.00481	0.98	5.19E 05
39.7	116.	2.99	85.	665.	521.	4.48	0.00470	0.94	5.21E 05
42.9	120.	2.90	88.	682.	540.	4.49	0.00454	0.99	5.10E 05
46.1	124.	2.81	91.	694.	553.	4.46	0.00444	0.88	5.07E 05
52.4	130.	2.68	95.	670.	527.	4.06	0.00479	0.89	5.56E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
128	A-4	0.3148	1845.	1838.	0.213	1.89	0.03	0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	66.	4.35	90.	407.	247.	3.76	0.01036	1.38	1.38E 06
7.9	69.	4.26	92.	*500.	345.	5.02	0.00684	1.04	9.92E 05
14.3	75.	4.09	96.	485.	329.	4.41	0.00743	1.08	1.07E 06
17.5	78.	4.00	98.	468.	311.	4.02	0.00807	1.13	1.15E 06
20.6	80.	3.91	101.	486.	330.	4.11	0.00755	1.07	1.09E 06
27.0	86.	3.74	105.	490.	335.	3.90	0.00759	1.05	1.10E 06
30.2	88.	3.66	108.	480.	324.	3.66	0.00802	1.08	1.16E 06
33.4	91.	3.58	110.	509.	354.	3.89	0.00719	0.99	1.07E 06
39.7	96.	3.42	115.	496.	341.	3.55	0.00771	1.01	1.14E 06
42.9	99.	3.34	118.	508.	353.	3.58	0.00744	0.97	1.12E 06
46.1	101.	3.26	121.	516.	362.	3.57	0.00727	0.95	1.10E 06
52.4	105.	3.15	125.	482.	326.	3.11	0.00853	1.04	1.26E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
130	A-4	0.3148	1513.	1509.	0.133	0.98	0.03	-0.07

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	93.	3.23	76.	332.	248.	2.66	0.00629	1.16	9.45E 05
7.9	95.	3.17	78.	322.	237.	2.49	0.00685	1.22	1.00E 06
14.3	99.	3.03	81.	329.	245.	2.47	0.00569	1.18	9.98E 05
17.5	101.	2.97	83.	356.	273.	2.70	0.00569	1.03	9.05E 05
20.6	103.	2.91	85.	397.	315.	3.06	0.00462	0.87	7.84E 05
27.0	107.	2.78	88.	371.	288.	2.70	0.00539	0.96	8.89E 05
30.2	109.	2.73	90.	370.	287.	2.64	0.00549	0.96	9.06E 05
33.4	111.	2.67	92.	357.	274.	2.47	0.00598	1.01	9.63E 05
39.7	115.	2.56	96.	378.	295.	2.57	0.00542	0.92	9.15E 05
42.9	116.	2.51	98.	357.	274.	2.35	0.00621	1.01	1.00E 06
46.1	118.	2.46	100.	*292.	207.	1.75	0.01098	1.58	1.33E 06
52.4	121.	2.39	103.	382.	299.	2.47	0.00550	0.89	9.43E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
131	A-4	0.3148	1488.	1482.	0.212	0.99	0.04	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	79.	3.71	106.	287.	201.	2.54	0.00799	0.99	1.68E 06
7.9	81.	3.67	107.	332.	247.	3.07	0.00587	0.81	1.39E 06
14.3	83.	3.57	110.	311.	226.	2.72	0.00684	0.89	1.55E 06
17.5	84.	3.52	112.	289.	203.	2.41	0.00819	1.00	1.71E 06
20.6	86.	3.48	113.	358.	274.	3.20	0.00520	0.73	1.29E 06
27.0	88.	3.38	116.	294.	208.	2.36	0.00812	0.98	1.72E 06
30.2	90.	3.34	118.	297.	211.	2.35	0.00804	0.97	1.72E 06
33.4	91.	3.29	119.	337.	252.	2.78	0.00606	0.79	1.45E 06
39.7	93.	3.20	123.	298.	213.	2.28	0.00818	0.97	1.75E 06
42.9	94.	3.16	124.	304.	218.	2.31	0.00788	0.94	1.72E 06
46.1	96.	3.12	126.	334.	250.	2.61	0.00634	0.80	1.52E 06
52.4	98.	3.05	129.	301.	216.	2.21	0.00825	0.96	1.77E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
133	A-4	0.3148	737.	732.	0.065	1.85	0.03	0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	119.	1.29	94.	651.	514.	4.33	0.00457	1.88	2.44E 05
7.9	127.	1.18	103.	1023.	905.	7.15	0.00238	1.40	1.19E 05
14.3	143.	1.00	121.	1076.	957.	6.69	0.00228	1.23	1.26E 05
17.5	151.	0.93	130.	1216.	1098.	7.26	0.00198	1.11	1.10E 05
20.6	159.	0.88	138.	1090.	971.	6.09	0.00229	1.14	1.38E 05
27.0	176.	0.78	155.	1123.	1004.	5.71	0.00225	1.05	1.44E 05
30.2	184.	0.74	163.	1208.	1090.	5.93	0.00207	0.98	1.34E 05
33.4	192.	0.71	171.	1128.	1010.	5.27	0.00228	0.99	1.54E 05
39.7	207.	0.65	186.	1163.	1045.	5.05	0.00223	0.94	1.56E 05
42.9	215.	0.62	194.	1152.	1034.	4.82	0.00228	0.93	1.64E 05
46.1	222.	0.60	201.	1134.	1016.	4.58	0.00235	0.92	1.72E 05
52.4	233.	0.57	211.	1099.	980.	4.21	0.00249	0.93	1.87E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
134	A-4	0.3148	939.	934.	0.079	1.85	0.03	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	110.	1.85	79.	612.	472.	4.28	0.00500	1.80	2.94E 05
7.9	116.	1.71	86.	895.	775.	6.69	0.00279	1.39	1.59E 05
14.3	128.	1.47	99.	986.	868.	6.77	0.00250	1.21	1.54E 05
17.5	135.	1.37	106.	1076.	958.	7.11	0.00226	1.12	1.41E 05
20.6	141.	1.29	114.	985.	867.	6.13	0.00255	1.12	1.72E 05
27.0	154.	1.15	127.	1071.	952.	6.17	0.00234	1.01	1.65E 05
30.2	161.	1.09	134.	1092.	973.	6.05	0.00230	0.97	1.67E 05
33.4	168.	1.04	140.	1031.	913.	5.45	0.00249	0.98	1.90E 05
39.7	181.	0.95	153.	1057.	938.	5.18	0.00245	0.92	1.96E 05
42.9	187.	0.92	159.	1026.	907.	4.85	0.00258	0.92	2.11E 05
46.1	193.	0.88	165.	1000.	881.	4.56	0.00270	0.92	2.25E 05
52.4	203.	0.84	174.	989.	871.	4.29	0.00277	0.91	2.38E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
136	A-4	0.3148	1563.	1557.	0.057	1.84	0.01	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	89.	3.44	31.	518.	369.	4.16	0.00650	2.85	2.53E 05
7.9	97.	3.14	34.	658.	518.	5.31	0.00438	2.17	1.76E 05
14.3	115.	2.62	40.	716.	580.	5.06	0.00397	1.88	1.75E 05
17.5	123.	2.40	44.	761.	629.	5.10	0.00366	1.73	1.68E 05
20.6	132.	2.21	48.	689.	552.	4.19	0.00439	1.79	2.12E 05
27.0	149.	1.90	55.	713.	578.	3.87	0.00431	1.64	2.25E 05
30.2	158.	1.77	59.	821.	694.	4.39	0.00348	1.49	1.88E 05
33.4	167.	1.67	63.	885.	761.	4.57	0.00314	1.39	1.75E 05
39.7	184.	1.49	71.	957.	836.	4.54	0.00288	1.25	1.69E 05
42.9	193.	1.41	74.	950.	828.	4.30	0.00295	1.24	1.77E 05
46.1	201.	1.35	78.	956.	835.	4.15	0.00296	1.21	1.81E 05
52.4	214.	1.26	83.	981.	860.	4.02	0.00291	1.16	1.83E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
138	A-4	0.3148	954.	953.	0.052	0.56	0.01	-0.06

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	78.	3.22	30.	359.	312.	3.99	0.00235	1.42	2.17E 05
7.9	81.	3.09	31.	369.	323.	4.00	0.00228	1.35	2.14E 05
14.3	85.	2.85	34.	413.	367.	4.29	0.00196	1.16	1.93E 05
17.5	88.	2.73	36.	430.	384.	4.37	0.00187	1.10	1.88E 05
20.6	90.	2.62	37.	429.	383.	4.25	0.00189	1.07	1.95E 05
27.0	95.	2.40	40.	446.	401.	4.21	0.00181	0.99	1.97E 05
30.2	97.	2.30	42.	456.	411.	4.22	0.00177	0.95	1.97E 05
33.4	100.	2.21	44.	449.	404.	4.04	0.00182	0.94	2.09E 05
39.7	105.	2.04	48.	482.	437.	4.17	0.00167	0.84	2.02E 05
42.9	107.	1.96	50.	487.	442.	4.12	0.00166	0.82	2.05E 05
46.1	110.	1.88	52.	474.	429.	3.91	0.00174	0.82	2.19E 05
52.4	114.	1.78	54.	481.	436.	3.83	0.00172	0.79	2.25E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
144	A-4	0.3148	2026.	2019.	0.208	1.84	0.04	-0.05

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	88.	3.78	102.	434.	279.	3.16	0.00968	1.21	1.35E 06
7.9	91.	3.70	104.	583.	436.	4.79	0.00540	0.79	8.46E 05
14.3	96.	3.54	109.	*500.	348.	3.61	0.00736	0.95	1.12E 06
17.5	99.	3.47	111.	441.	286.	2.89	0.00985	1.17	1.39E 06
20.6	102.	3.39	113.	488.	335.	3.30	0.00793	0.98	1.20E 06
27.0	107.	3.25	118.	503.	351.	3.29	0.00759	0.93	1.18E 06
30.2	109.	3.18	121.	480.	327.	2.99	0.00850	1.00	1.28E 06
33.4	112.	3.12	124.	506.	354.	3.17	0.00765	0.92	1.20E 06
39.7	117.	2.99	129.	477.	325.	2.78	0.00890	1.00	1.34E 06
42.9	119.	2.93	131.	*500.	348.	2.93	0.00809	0.93	1.27E 06
46.1	121.	2.87	134.	523.	373.	3.07	0.00739	0.86	1.19E 06
52.4	125.	2.79	138.	495.	343.	2.74	0.00852	0.94	1.33E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
170	A-4	0.3148	853.	840.	0.421	1.82	0.08	-0.16

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	59.	4.03	193.	*400.	243.	4.13	0.00993	1.26	1.93E 06
7.9	60.	3.97	196.	394.	237.	3.93	0.01038	1.28	2.01E 06
14.3	63.	3.86	202.	408.	252.	4.01	0.00969	1.23	1.88E 06
17.5	64.	3.80	205.	387.	229.	3.58	0.01107	1.31	2.14E 06
20.6	65.	3.74	208.	425.	270.	4.14	0.00896	1.16	1.74E 06
27.0	68.	3.62	215.	432.	278.	4.10	0.00875	1.13	1.71E 06
30.2	69.	3.56	218.	397.	240.	3.49	0.01069	1.25	2.09E 06
33.4	70.	3.51	222.	423.	268.	3.83	0.00928	1.15	1.84E 06
39.7	72.	3.39	230.	406.	250.	3.47	0.01029	1.20	2.05E 06
42.9	73.	3.33	234.	416.	261.	3.57	0.00977	1.16	1.96E 06
46.1	74.	3.27	238.	441.	286.	3.87	0.00855	1.06	1.76E 06
52.4	76.	3.18	245.	420.	264.	3.50	0.00971	1.13	1.99E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
171	A-4	0.3148	921.	903.	0.421	2.81	0.08	-0.07

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	57.	4.16	187.	*500.	265.	4.65	0.01357	1.73	1.79E 06
7.9	59.	4.07	191.	535.	302.	5.12	0.01152	1.58	1.51E 06
14.3	63.	3.90	200.	552.	321.	5.08	0.01097	1.49	1.42E 06
17.5	65.	3.81	204.	583.	355.	5.44	0.00980	1.37	1.26E 06
20.6	67.	3.72	209.	553.	323.	4.80	0.01108	1.47	1.46E 05
27.0	71.	3.54	220.	574.	345.	4.88	0.01032	1.36	1.37E 06
30.2	72.	3.45	225.	613.	388.	5.36	0.00901	1.24	1.19E 06
33.4	74.	3.37	231.	580.	351.	4.74	0.01023	1.31	1.39E 06
39.7	77.	3.19	244.	637.	414.	5.35	0.00845	1.14	1.16E 06
42.9	79.	3.11	250.	629.	406.	5.14	0.00871	1.14	1.22E 06
46.1	80.	3.02	257.	606.	380.	4.73	0.00948	1.18	1.36E 06
52.4	83.	2.90	268.	*600.	374.	4.52	0.00977	1.17	1.43E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
172	A-4	0.3148	2056.	2045.	0.431	1.91	0.06	-0.14

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	67.	4.41	181.	350.	181.	2.71	0.01689	1.08	3.21E 06
7.9	68.	4.37	183.	361.	194.	2.83	0.01538	1.00	3.21E 06
14.3	71.	4.29	186.	372.	205.	2.87	0.01447	0.95	3.20E 06
17.5	73.	4.24	188.	373.	206.	2.83	0.01445	0.95	3.22E 06
20.6	74.	4.20	190.	370.	203.	2.73	0.01502	0.97	3.26E 06
27.0	77.	4.11	194.	379.	212.	2.74	0.01431	0.94	3.25E 06
30.2	79.	4.07	196.	382.	216.	2.74	0.01411	0.92	3.24E 06
33.4	80.	4.03	198.	371.	204.	2.55	0.01555	0.99	3.35E 06
39.7	83.	3.94	202.	387.	221.	2.66	0.01401	0.91	3.26E 06
42.9	85.	3.90	204.	369.	202.	2.38	0.01648	1.03	3.45E 06
46.1	86.	3.86	207.	408.	244.	2.84	0.01225	0.81	3.10E 06
52.4	88.	3.80	210.	388.	222.	2.52	0.01442	0.92	3.33E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
173	A-4	0.3148	1983.	1970.	0.430	2.66	0.06	-0.10

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
4.8	69.	4.32	184.	430.	200.	2.90	0.02043	1.35	3.21E 06
7.9	71.	4.26	187.	442.	213.	2.99	0.01888	1.28	3.15E 06
14.3	75.	4.13	192.	465.	238.	3.16	0.01646	1.15	3.00E 06
17.5	77.	4.07	195.	487.	262.	3.38	0.01458	1.05	2.81E 06
20.6	79.	4.01	198.	451.	223.	2.81	0.01864	1.25	3.19E 06
27.0	83.	3.89	204.	473.	247.	2.96	0.01639	1.12	3.02E 06
30.2	85.	3.84	207.	496.	272.	3.18	0.01444	1.02	2.81E 06
33.4	87.	3.78	210.	463.	237.	2.71	0.01796	1.19	3.17E 06
39.7	91.	3.67	217.	*500.	277.	3.04	0.01450	1.00	2.93E 06
42.9	93.	3.61	220.	*474.	248.	2.66	0.01736	1.14	3.15E 06
46.1	95.	3.55	224.	470.	244.	2.57	0.01804	1.17	3.22E 06
52.4	98.	3.47	229.	*500.	276.	2.83	0.01505	1.01	2.93E 06

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
184	A-5	0.2110	1628.	1610.	0.143	1.94	0.06	0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	70.	4.10	143.	287.	170.	2.42	0.01952	1.47	1.75E 06
11.8	73.	4.01	147.	327.	213.	2.91	0.01399	1.19	1.57E 06
21.3	79.	3.82	154.	340.	226.	2.86	0.01331	1.14	1.54E 06
26.1	82.	3.72	158.	355.	242.	2.96	0.01221	1.07	1.46E 06
30.8	85.	3.63	162.	347.	234.	2.77	0.01310	1.11	1.53E 06
40.3	90.	3.45	170.	358.	246.	2.74	0.01258	1.06	1.51E 06
45.0	92.	3.36	175.	406.	296.	3.20	0.00967	0.87	1.27E 06
49.8	95.	3.27	179.	364.	251.	2.65	0.01253	1.03	1.52E 06
59.2	100.	3.11	189.	381.	270.	2.70	0.01157	0.95	1.46E 06
64.0	102.	3.03	194.	364.	252.	2.46	0.01313	1.03	1.59E 06
68.7	105.	2.95	199.	400.	289.	2.76	0.01066	0.87	1.41E 06
78.2	109.	2.84	207.	400.	289.	2.66	0.01088	0.86	1.44E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
185	A-5	0.2110	1474.	1445.	0.206	1.95	0.08	0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	64.	4.23	201.	263.	143.	2.24	0.02481	1.34	2.56E 06
11.8	66.	4.15	204.	283.	165.	2.49	0.02003	1.15	2.55E 06
21.3	70.	4.01	211.	292.	175.	2.49	0.01886	1.11	2.54E 06
26.1	72.	3.94	215.	308.	192.	2.65	0.01651	1.02	2.42E 06
30.8	74.	3.87	219.	296.	179.	2.40	0.01893	1.11	2.57E 06
40.3	78.	3.73	227.	302.	186.	2.37	0.01840	1.09	2.56E 06
45.0	80.	3.66	232.	329.	214.	2.67	0.01480	0.95	2.31E 06
49.8	82.	3.59	236.	311.	195.	2.37	0.01755	1.06	2.53E 06
59.2	86.	3.46	245.	331.	216.	2.53	0.01512	0.95	2.35E 06
64.0	87.	3.39	250.	314.	198.	2.26	0.01791	1.06	2.58E 06
68.7	89.	3.32	255.	*300.	183.	2.06	0.02093	1.17	2.77E 06
78.2	92.	3.23	263.	*300.	183.	2.00	0.02152	1.19	2.82E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
186	A-5	0.2110	1429.	1420.	0.068	1.95	0.03	0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	83.	3.52	79.	436.	328.	3.94	0.00797	1.52	4.83E 05
11.8	88.	3.32	84.	505.	399.	4.51	0.00630	1.26	3.94E 05
21.3	99.	2.95	94.	547.	443.	4.49	0.00570	1.10	3.77E 05
26.1	104.	2.78	100.	565.	462.	4.45	0.00549	1.05	3.73E 05
30.8	109.	2.63	106.	575.	472.	4.33	0.00542	1.01	3.80E 05
40.3	119.	2.35	119.	624.	523.	4.40	0.00488	0.90	3.63E 05
45.0	124.	2.23	125.	627.	527.	4.25	0.00490	0.88	3.75E 05
49.8	129.	2.11	132.	663.	565.	4.38	0.00454	0.82	3.57E 05
59.2	140.	1.91	146.	607.	506.	3.63	0.00538	0.85	4.42E 05
64.0	145.	1.82	153.	*587.	485.	3.35	0.00579	0.86	4.81E 05
68.7	150.	1.74	160.	*600.	499.	3.33	0.00565	0.83	4.80E 05
78.2	158.	1.64	170.	*600.	499.	3.16	0.00578	0.82	5.01E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
187	A-5	0.2110	1504.	1498.	0.071	1.11	0.03	0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	77.	3.82	76.	262.	198.	2.58	0.00904	1.31	8.36E 05
11.8	80.	3.71	79.	277.	213.	2.67	0.00820	1.23	7.98E 05
21.3	86.	3.50	83.	294.	230.	2.69	0.00758	1.14	7.69E 05
26.1	88.	3.39	86.	312.	249.	2.81	0.00685	1.05	7.25E 05
30.8	91.	3.29	89.	306.	243.	2.66	0.00725	1.08	7.58E 05
40.3	97.	3.10	94.	315.	251.	2.60	0.00710	1.04	7.59E 05
45.0	100.	3.00	97.	411.	351.	3.52	0.00440	0.72	5.36E 05
49.8	102.	2.91	100.	323.	260.	2.54	0.00695	0.99	7.61E 05
59.2	108.	2.74	107.	339.	276.	2.56	0.00653	0.91	7.44E 05
64.0	111.	2.66	110.	312.	249.	2.25	0.00792	1.05	8.42E 05
68.7	113.	2.59	113.	*300.	236.	2.09	0.00891	1.13	9.03E 05
78.2	117.	2.48	118.	322.	259.	2.21	0.00775	0.99	8.48E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
188	A-5	0.2110	1540.	1529.	0.069	2.44	0.03	0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	82.	3.67	77.	518.	386.	4.73	0.00800	1.58	4.09E 05
11.8	88.	3.43	82.	657.	534.	6.04	0.00552	1.26	2.82E 05
21.3	101.	2.98	95.	734.	616.	6.07	0.00481	1.10	2.60E 05
26.1	108.	2.78	102.	753.	635.	5.89	0.00469	1.04	2.63E 05
30.8	114.	2.60	109.	776.	661.	5.79	0.00454	1.00	2.64E 05
40.3	127.	2.29	124.	858.	748.	5.89	0.00402	0.92	2.49E 05
45.0	133.	2.15	131.	820.	707.	5.31	0.00433	0.90	2.81E 05
49.8	140.	2.02	140.	863.	753.	5.38	0.00407	0.86	2.72E 05
59.2	153.	1.82	155.	756.	639.	4.18	0.00509	0.86	3.64E 05
64.0	159.	1.73	163.	749.	631.	3.97	0.00524	0.85	3.83E 05
68.7	166.	1.65	171.	*600.	473.	2.86	0.00797	1.04	5.60E 05
78.2	175.	1.55	183.	583.	455.	2.60	0.00875	1.07	6.10E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
189	A-5	0.2110	1413.	1378.	0.204	2.49	0.08	0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	67.	4.10	205.	312.	164.	2.46	0.02572	1.49	2.56E 06
11.8	69.	4.01	210.	344.	198.	2.85	0.01948	1.28	2.30E 06
21.3	74.	3.83	220.	360.	215.	2.89	0.01783	1.22	2.19E 06
26.1	77.	3.74	225.	379.	236.	3.07	0.01582	1.12	2.03E 06
30.8	79.	3.65	231.	367.	222.	2.81	0.01752	1.19	2.18E 06
40.3	84.	3.47	243.	388.	245.	2.92	0.01563	1.09	2.03E 06
45.0	86.	3.38	249.	397.	254.	2.95	0.01496	1.04	1.98E 06
49.8	88.	3.29	255.	395.	252.	2.86	0.01534	1.05	2.03E 06
59.2	93.	3.13	269.	403.	261.	2.82	0.01495	1.01	2.01E 06
64.0	95.	3.05	276.	393.	250.	2.64	0.01621	1.05	2.14E 06
68.7	97.	2.97	283.	*400.	258.	2.66	0.01554	1.02	2.11E 06
78.2	100.	2.85	295.	*400.	258.	2.57	0.01596	1.01	2.16E 06

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
190	A-5	0.2110	1497.	1474.	0.143	2.49	0.06	0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	71.	4.01	147.	356.	211.	2.98	0.01782	1.57	1.56E 06
11.8	74.	3.89	152.	407.	266.	3.57	0.01310	1.29	1.26E 06
21.3	81.	3.64	162.	429.	289.	3.55	0.01210	1.19	1.19E 06
26.1	85.	3.52	168.	445.	305.	3.60	0.01141	1.12	1.14E 06
30.8	88.	3.40	174.	440.	301.	3.42	0.01183	1.13	1.19E 06
40.3	94.	3.17	186.	465.	326.	3.45	0.01088	1.03	1.13E 06
45.0	97.	3.06	193.	469.	330.	3.39	0.01082	1.00	1.14E 06
49.8	101.	2.95	*200.	478.	340.	3.38	0.01051	0.96	1.13E 06
59.2	107.	2.75	214.	474.	336.	3.14	0.01101	0.96	1.20E 06
64.0	110.	2.66	222.	460.	321.	2.92	0.01191	0.99	1.29E 06
68.7	113.	2.57	229.	*500.	363.	3.21	0.01010	0.87	1.15E 06
78.2	118.	2.45	241.	*500.	363.	3.09	0.01029	0.86	1.19E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
191	A-5	0.2110	1457.	1433.	0.206	1.05	0.07	0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	64.	4.21	202.	188.	122.	1.90	0.01806	0.93	2.50E 06
11.8	65.	4.17	203.	181.	114.	1.75	0.02128	1.07	2.47E 06
21.3	67.	4.10	207.	184.	117.	1.74	0.02087	1.04	2.56E 06
26.1	69.	4.06	209.	205.	141.	2.05	0.01442	0.76	2.68E 06
30.8	70.	4.02	211.	191.	124.	1.78	0.01906	0.96	2.67E 06
40.3	72.	3.95	215.	189.	122.	1.70	0.02057	1.02	2.72E 06
45.0	73.	3.91	217.	210.	146.	2.00	0.01423	0.75	2.77E 06
49.8	74.	3.87	219.	190.	123.	1.67	0.02104	1.03	2.79E 06
59.2	76.	3.80	224.	225.	161.	2.12	0.01217	0.67	2.75E 06
64.0	77.	3.76	226.	201.	136.	1.76	0.01768	0.89	2.89E 06
68.7	78.	3.72	228.	*200.	135.	1.73	0.01833	0.92	2.92E 06
78.2	79.	3.67	232.	222.	159.	2.00	0.01313	0.70	2.84E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
192	A-5	0.2110	1601.	1587.	0.142	1.07	0.05	0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	68.	4.17	140.	188.	120.	1.77	0.02024	1.38	1.69E 06
11.8	69.	4.12	142.	200.	134.	1.93	0.01642	1.14	1.77E 06
21.3	73.	4.01	146.	210.	144.	1.98	0.01483	1.04	1.83E 06
26.1	74.	3.96	148.	225.	161.	2.17	0.01226	0.89	1.83E 06
30.8	76.	3.91	150.	221.	156.	2.06	0.01315	0.94	1.86E 06
40.3	79.	3.81	154.	217.	152.	1.93	0.01452	1.01	1.92E 06
45.0	80.	3.75	156.	233.	169.	2.10	0.01198	0.87	1.88E 06
49.8	82.	3.70	158.	218.	153.	1.88	0.01480	1.02	1.96E 06
59.2	85.	3.60	163.	242.	178.	2.11	0.01134	0.83	1.88E 06
64.0	86.	3.55	165.	*200.	133.	1.54	0.02261	1.45	2.07E 06
68.7	87.	3.50	167.	*200.	133.	1.52	0.02306	1.47	2.10E 06
78.2	90.	3.43	171.	224.	159.	1.78	0.01526	1.03	2.06E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
193	A-5	0.2110	1546.	1523.	0.140	2.50	0.06	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	77.	3.83	151.	492.	354.	4.60	0.00912	1.00	9.04E 05
11.8	81.	3.71	156.	416.	275.	3.41	0.01296	1.26	1.24E 06
21.3	87.	3.46	167.	436.	296.	3.38	0.01207	1.16	1.19E 06
26.1	91.	3.34	173.	446.	306.	3.37	0.01171	1.11	1.17E 06
30.8	94.	3.23	179.	449.	309.	3.28	0.01173	1.09	1.18E 06
40.3	101.	3.01	192.	469.	330.	3.28	0.01101	1.00	1.15E 06
45.0	104.	2.90	199.	464.	324.	3.13	0.01143	1.01	1.20E 06
49.8	107.	2.80	206.	479.	341.	3.18	0.01080	0.95	1.16E 06
59.2	113.	2.62	220.	472.	334.	2.95	0.01145	0.96	1.25E 06
64.0	116.	2.53	228.	465.	326.	2.80	0.01203	0.97	1.31E 06
68.7	120.	2.45	235.	*500.	363.	3.03	0.01041	0.86	1.19E 06
78.2	124.	2.33	247.	445.	305.	2.45	0.01398	1.04	1.48E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
195	A-5	0.2110	1471.	1449.	0.143	2.50	0.06	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	69.	4.04	145.	542.	407.	5.86	0.00749	0.93	7.23E 05
11.8	73.	3.91	150.	414.	272.	3.72	0.01258	1.28	1.20E 06
21.3	80.	3.66	160.	433.	293.	3.66	0.01178	1.19	1.15E 06
26.1	84.	3.54	166.	445.	306.	3.66	0.01131	1.14	1.12E 06
30.8	87.	3.42	172.	447.	307.	3.54	0.01141	1.12	1.14E 06
40.3	93.	3.18	185.	468.	329.	3.53	0.01067	1.03	1.10E 06
45.0	96.	3.07	191.	465.	326.	3.39	0.01094	1.03	1.14E 06
49.8	99.	2.96	198.	481.	343.	3.45	0.01035	0.97	1.10E 06
59.2	106.	2.76	213.	473.	335.	3.17	0.01097	0.97	1.18E 06
64.0	109.	2.66	221.	466.	328.	3.01	0.01148	0.98	1.24E 06
68.7	112.	2.57	228.	*500.	363.	3.25	0.01004	0.88	1.13E 06
78.2	116.	2.45	240.	441.	301.	2.59	0.01362	1.06	1.45E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
196	A-5	0.2110	1544.	1521.	0.143	2.49	0.06	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	76.	3.86	152.	542.	407.	5.36	0.00764	0.89	7.68E 05
11.8	80.	3.74	157.	436.	296.	3.72	0.01161	1.15	1.15E 06
21.3	86.	3.50	168.	436.	296.	3.43	0.01198	1.14	1.20E 06
26.1	90.	3.38	174.	450.	311.	3.47	0.01135	1.08	1.16E 06
30.8	93.	3.27	180.	464.	325.	3.50	0.01082	1.02	1.13E 06
40.3	99.	3.05	193.	463.	325.	3.27	0.01117	1.01	1.18E 06
45.0	102.	2.95	199.	466.	328.	3.20	0.01117	0.99	1.20E 06
49.8	106.	2.84	206.	479.	341.	3.23	0.01069	0.94	1.17E 06
59.2	112.	2.66	221.	475.	337.	3.01	0.01118	0.93	1.24E 06
64.0	115.	2.57	228.	476.	338.	2.95	0.01126	0.92	1.26E 06
68.7	118.	2.49	236.	*500.	363.	3.08	0.01029	0.85	1.19E 06
78.2	123.	2.37	247.	447.	307.	2.51	0.01359	1.01	1.48E 06

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
197	A-6A	0.2110	1391.	1380.	0.149	2.16	0.06	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	74.	3.81	161.	393.	272.	3.66	0.01083	1.09	1.24E 06
11.8	77.	3.71	166.	374.	252.	3.26	0.01222	1.16	1.37E 06
21.3	83.	3.50	175.	381.	260.	3.14	0.01208	1.13	1.37E 06
26.1	85.	3.40	181.	404.	284.	3.32	0.01081	1.03	1.27E 06
30.8	88.	3.30	186.	399.	279.	3.17	0.01123	1.04	1.32E 06
35.5	90.	3.20	192.	403.	283.	3.13	0.01111	1.02	1.32E 06
40.3	94.	3.06	201.	396.	276.	2.93	0.01181	1.04	1.40E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
200	A-6A	0.2110	1489.	1468.	0.203	4.04	0.07	-0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	66.	4.16	201.	513.	290.	4.38	0.01810	1.48	1.55E 06
11.8	71.	4.01	208.	564.	345.	4.89	0.01481	1.27	1.28E 06
21.3	79.	3.72	224.	598.	382.	4.84	0.01347	1.16	1.18E 06
26.1	83.	3.58	233.	593.	377.	4.56	0.01386	1.15	1.23E 06
30.8	86.	3.44	243.	632.	419.	4.84	0.01231	1.05	1.11E 06
35.5	90.	3.30	253.	617.	402.	4.46	0.01308	1.06	1.20E 06
40.3	96.	3.11	268.	628.	415.	4.35	0.01278	1.01	1.20E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
201	A-6A	0.2110	1584.	1576.	0.075	4.09	0.03	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	88.	3.48	89.	859.	675.	7.68	0.00689	1.71	2.27E 05
11.8	98.	3.14	98.	1183.	1008.	10.29	0.00455	1.47	1.40E 05
21.3	118.	2.56	121.	1309.	1134.	9.63	0.00410	1.23	1.41E 05
26.1	127.	2.32	133.	1214.	1039.	8.15	0.00455	1.20	1.74E 05
30.8	137.	2.12	146.	1261.	1086.	7.90	0.00438	1.11	1.76E 05
35.5	147.	1.95	159.	1188.	1013.	6.87	0.00478	1.09	2.09E 05
40.3	162.	1.74	178.	1178.	1003.	6.20	0.00492	1.03	2.32E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
203	A-6A	0.2110	1517.	1498.	0.148	5.42	0.05	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	72.	3.98	153.	754.	488.	6.78	0.01292	1.67	6.07E 05
11.8	79.	3.72	164.	939.	699.	8.79	0.00880	1.41	3.89E 05
21.3	93.	3.23	189.	1073.	838.	8.98	0.00738	1.29	3.38E 05
26.1	100.	3.00	203.	1071.	836.	8.36	0.00747	1.23	3.61E 05
30.8	107.	2.78	219.	1161.	926.	8.68	0.00675	1.14	3.32E 05
35.5	113.	2.59	235.	1131.	896.	7.92	0.00705	1.11	3.69E 05
40.3	123.	2.34	260.	1113.	878.	7.15	0.00730	1.05	4.14E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
204	A-6A	0.2110	1598.	1593.	0.071	2.20	0.03	0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	76.	3.89	76.	495.	378.	4.96	0.00720	1.38	4.30E 05
11.8	82.	3.68	80.	527.	411.	4.98	0.00663	1.28	4.02E 05
21.3	94.	3.29	89.	599.	487.	5.18	0.00557	1.09	3.51E 05
26.1	100.	3.10	95.	605.	493.	4.95	0.00557	1.06	3.61E 05
30.8	105.	2.93	101.	636.	526.	5.00	0.00522	1.00	3.47E 05
35.5	111.	2.76	106.	659.	550.	4.97	0.00500	0.95	3.42E 05
40.3	119.	2.55	115.	666.	557.	4.70	0.00501	0.90	3.58E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
206	A-6A	0.2110	1461.	1440.	0.147	5.58	0.05	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	71.	4.00	151.	804.	539.	7.64	0.01180	1.69	5.12E 05
11.8	78.	3.72	163.	1010.	768.	9.81	0.00814	1.50	3.29E 05
21.3	92.	3.20	189.	1171.	930.	10.05	0.00677	1.31	2.82E 05
26.1	99.	2.96	205.	1145.	904.	9.10	0.00704	1.26	3.15E 05
30.8	106.	2.74	221.	1203.	961.	9.05	0.00665	1.18	3.08E 05
35.5	113.	2.54	239.	1159.	917.	8.13	0.00704	1.14	3.50E 05
40.3	123.	2.28	266.	1123.	882.	7.18	0.00745	1.09	4.06E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
207	A-6A	0.2110	2027.	2013.	0.149	4.23	0.05	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	76.	4.13	149.	537.	309.	4.04	0.01815	1.58	1.25E 06
11.8	83.	3.95	155.	597.	373.	4.51	0.01459	1.33	1.04E 06
21.3	94.	3.60	170.	646.	427.	4.53	0.01276	1.16	9.41E 05
26.1	100.	3.44	178.	657.	439.	4.40	0.01253	1.12	9.38E 05
30.8	105.	3.28	187.	669.	452.	4.29	0.01226	1.08	9.35E 05
35.5	111.	3.14	196.	703.	490.	4.43	0.01123	1.01	8.75E 05
40.3	119.	2.94	209.	697.	483.	4.07	0.01168	1.00	9.33E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
209	A-6A	0.2110	2197.	2190.	0.071	3.90	0.02	0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	96.	3.66	80.	767.	582.	6.06	0.00795	1.51	3.18E 05
11.8	107.	3.36	87.	931.	761.	7.11	0.00597	1.37	2.41E 05
21.3	128.	2.87	102.	1075.	907.	7.09	0.00507	1.18	2.15E 05
26.1	138.	2.65	110.	1083.	915.	6.61	0.00508	1.13	2.26E 05
30.8	149.	2.47	118.	1171.	1003.	6.75	0.00465	1.04	2.11E 05
35.5	159.	2.31	126.	1179.	1011.	6.38	0.00466	1.00	2.21E 05
40.3	173.	2.10	139.	1152.	984.	5.67	0.00489	0.97	2.46E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
215	A-6A	0.2110	1850.	1850.	0.150	4.14	0.05	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	74.	4.12	150.	557.	333.	4.51	0.01604	1.51	1.11E 06
11.8	80.	3.94	157.	625.	407.	5.11	0.01273	1.27	8.98E 05
21.3	91.	3.59	172.	671.	457.	5.03	0.01143	1.13	8.28E 05
26.1	96.	3.42	181.	665.	451.	4.67	0.01182	1.12	8.71E 05
30.8	102.	3.26	190.	702.	492.	4.84	0.01074	1.05	8.08E 05
35.5	107.	3.11	199.	707.	498.	4.66	0.01073	1.02	8.24E 05
40.3	115.	2.90	213.	713.	504.	4.40	0.01077	0.99	8.53E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
218	A-6A	0.2110	1020.	1020.	0.149	4.03	0.06	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	69.	3.75	164.	608.	397.	5.78	0.01221	1.83	6.28E 05
11.8	74.	3.52	174.	740.	542.	7.37	0.00864	1.49	4.26E 05
21.3	83.	3.09	199.	874.	691.	8.35	0.00672	1.26	3.37E 05
26.1	87.	2.88	213.	859.	674.	7.75	0.00695	1.22	3.71E 05
30.8	91.	2.69	229.	904.	723.	7.91	0.00649	1.15	3.56E 05
35.5	96.	2.50	245.	883.	700.	7.32	0.00676	1.11	3.97E 05
40.3	102.	2.26	272.	840.	652.	6.39	0.00741	1.06	4.80E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
223	A-6A	0.2110	983.	983.	0.205	4.33	0.08	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	64.	3.93	215.	531.	294.	4.61	0.01873	2.01	1.22E 06
11.8	68.	3.75	226.	608.	379.	5.58	0.01395	1.63	8.96E 05
21.3	75.	3.39	249.	719.	502.	6.66	0.01026	1.30	6.55E 05
26.1	79.	3.22	263.	730.	514.	6.51	0.01008	1.25	6.62E 05
30.8	82.	3.05	277.	779.	569.	6.91	0.00904	1.16	6.01E 05
35.5	86.	2.88	293.	815.	608.	7.10	0.00843	1.09	5.73E 05
40.3	91.	2.65	319.	782.	571.	6.30	0.00915	1.06	6.72E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
224	A-6A	0.2110	959.	959.	0.149	2.13	0.06	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	64.	3.88	158.	375.	253.	3.93	0.01137	1.47	1.07E 06
11.8	67.	3.76	163.	420.	300.	4.46	0.00925	1.28	8.72E 05
21.3	72.	3.52	174.	443.	324.	4.48	0.00856	1.18	8.23E 05
26.1	75.	3.39	180.	440.	321.	4.29	0.00876	1.17	8.55E 05
30.8	77.	3.27	187.	503.	386.	5.01	0.00699	0.99	6.85E 05
35.5	80.	3.15	194.	441.	322.	4.05	0.00888	1.13	8.98E 05
40.3	83.	2.98	205.	476.	358.	4.32	0.00785	1.00	8.16E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
226	A-6A	0.2110	2023.	2023.	0.259	6.90	0.09	-0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	72.	4.26	251.	656.	276.	3.84	0.03500	1.90	2.37E 06
11.8	78.	4.08	262.	697.	323.	4.14	0.02918	1.64	2.08E 06
21.3	90.	3.74	286.	771.	410.	4.57	0.02246	1.32	1.68E 06
26.1	95.	3.58	299.	515.	108.	1.13	0.57043	21.46	3.41E 06
30.8	101.	3.42	312.	*800.	445.	4.43	0.02093	1.20	1.61E 06
35.5	106.	3.27	327.	850.	504.	4.76	0.01817	1.10	1.43E 06
40.3	114.	3.06	349.	837.	489.	4.30	0.01926	1.09	1.56E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
228	A-6A	0.2110	2024.	2024.	0.258	5.24	0.09	-0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	69.	4.34	245.	523.	226.	3.27	0.03415	1.73	2.71E 06
11.8	74.	4.20	253.	551.	256.	3.47	0.02939	1.54	2.53E 06
21.3	83.	3.94	270.	597.	308.	3.71	0.02391	1.30	2.22E 06
26.1	87.	3.81	279.	551.	257.	2.95	0.03156	1.57	2.67E 06
30.8	91.	3.69	289.	599.	310.	3.39	0.02461	1.28	2.29E 06
35.5	96.	3.56	298.	639.	356.	3.72	0.02075	1.11	2.03E 06
40.3	102.	3.39	314.	616.	329.	3.24	0.02366	1.19	2.27E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
229	A-6A	0.2110	1792.	1792.	0.257	3.30	0.09	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	66.	4.31	246.	406.	216.	3.26	0.02218	1.17	2.74E 06
11.8	69.	4.22	251.	441.	254.	3.66	0.01804	1.02	2.45E 06
21.3	75.	4.04	262.	445.	258.	3.44	0.01823	1.01	2.47E 06
26.1	78.	3.96	268.	439.	252.	3.23	0.01919	1.04	2.55E 06
30.8	81.	3.87	273.	469.	284.	3.52	0.01644	0.93	2.30E 06
35.5	83.	3.79	279.	443.	256.	3.07	0.01935	1.03	2.58E 06
40.3	87.	3.67	289.	456.	270.	3.10	0.01827	0.98	2.50E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
230	A-6A	0.2110	1483.	1483.	0.143	5.57	0.07	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	105.	2.81	210.	734.	449.	4.28	0.01646	1.66	8.33E 05
11.8	112.	2.61	226.	797.	522.	4.66	0.01389	1.47	7.30E 05
21.3	126.	2.25	262.	962.	708.	5.63	0.00989	1.21	5.51E 05
26.1	133.	2.10	281.	917.	659.	4.95	0.01093	1.18	6.40E 05
30.8	140.	1.96	300.	1018.	768.	5.48	0.00921	1.10	5.52E 05
35.5	148.	1.85	320.	1073.	824.	5.59	0.00858	1.03	5.27E 05
40.3	158.	1.70	348.	1027.	778.	4.92	0.00934	1.02	6.09E 05

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
243	A-6A	0.2110	1466.	1441.	0.151	5.70	0.07	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	100.	2.95	211.	*800.	517.	5.17	0.01405	1.56	7.01E 05
11.8	107.	2.73	228.	880.	609.	5.70	0.01174	1.38	6.00E 05
21.3	120.	2.35	265.	999.	741.	6.16	0.00957	1.22	5.20E 05
26.1	127.	2.19	285.	966.	705.	5.55	0.01026	1.19	5.89E 05
30.8	134.	2.04	305.	1051.	795.	5.93	0.00901	1.10	5.29E 05
35.5	141.	1.91	326.	1059.	803.	5.68	0.00901	1.06	5.51E 05
40.3	152.	1.74	357.	1050.	795.	5.24	0.00927	1.02	6.00E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
245	A-6A	0.2110	1543.	1536.	0.072	2.97	0.05	0.07

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	137.	2.09	142.	*500.	338.	2.47	0.01472	1.80	7.36E 05
11.8	144.	1.96	152.	592.	436.	3.02	0.01024	1.35	5.79E 05
21.3	159.	1.74	170.	653.	501.	3.16	0.00875	1.17	5.32E 05
26.1	166.	1.65	180.	671.	521.	3.13	0.00847	1.12	5.28E 05
30.8	174.	1.57	189.	681.	531.	3.05	0.00841	1.09	5.33E 05
35.5	181.	1.49	199.	723.	576.	3.18	0.00762	1.01	5.00E 05
40.3	192.	1.40	212.	661.	510.	2.65	0.00944	1.11	6.00E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
246	A-6A	0.2110	1543.	1531.	0.136	2.32	0.07	0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	99.	3.08	182.	*400.	268.	2.72	0.01378	1.20	1.38E 06
11.8	102.	2.97	188.	409.	278.	2.73	0.01330	1.15	1.36E 06
21.3	108.	2.78	201.	390.	257.	2.38	0.01564	1.26	1.54E 06
26.1	111.	2.69	207.	428.	297.	2.68	0.01256	1.05	1.35E 06
30.8	114.	2.61	214.	427.	296.	2.60	0.01282	1.04	1.38E 06
35.5	117.	2.53	221.	434.	304.	2.60	0.01251	1.01	1.37E 06
40.3	121.	2.41	232.	404.	273.	2.24	0.01546	1.16	1.58E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
247	A-6A	0.2110	1727.	1710.	0.215	2.38	0.08	0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	85.	3.70	239.	350.	211.	2.49	0.01893	1.07	2.53E 06
11.8	87.	3.62	244.	353.	215.	2.47	0.01878	1.06	2.53E 06
21.3	91.	3.48	254.	366.	228.	2.50	0.01749	0.99	2.47E 06
26.1	93.	3.41	260.	375.	238.	2.55	0.01657	0.95	2.41E 06
30.8	95.	3.34	265.	382.	246.	2.57	0.01599	0.92	2.37E 06
35.5	98.	3.27	270.	374.	237.	2.43	0.01722	0.96	2.48E 06
40.3	101.	3.17	279.	413.	278.	2.76	0.01358	0.79	2.17E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
248	A-6A	0.2110	1468.	1462.	0.085	3.80	0.06	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	169.	1.55	226.	900.	733.	4.33	0.00672	1.01	4.16E 05
11.8	177.	1.47	239.	980.	817.	4.60	0.00596	0.93	3.76E 05
21.3	193.	1.34	262.	1137.	974.	5.04	0.00493	0.80	3.19E 05
26.1	201.	1.28	274.	1092.	929.	4.62	0.00527	0.81	3.51E 05
30.8	209.	1.23	286.	1181.	1018.	4.88	0.00477	0.75	3.21E 05
35.5	216.	1.18	297.	1223.	1059.	4.89	0.00459	0.72	3.13E 05
40.3	228.	1.12	314.	1167.	1003.	4.41	0.00497	0.73	3.50E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
251	A-6B	0.2110	1463.	-1203.	0.257	7.35	0.09	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	67.	3.79	280.	985.	653.	9.81	0.01275	1.79	5.06E 05
11.8	72.	3.54	299.	1100.	776.	10.80	0.01069	1.59	4.13E 05
16.6	77.	3.29	322.	1184.	860.	11.20	0.00967	1.58	3.76E 05
21.3	81.	3.05	347.	1201.	878.	10.78	0.00952	1.49	3.90E 05
27.3	87.	2.77	383.	1202.	878.	10.08	0.00959	1.40	4.25E 05
32.0	93.	2.51	423.	1029.	701.	7.57	0.01232	1.37	6.46E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
257	A-6B	0.2110	1463.	3862.	0.427	10.16	0.14	0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	70.	4.25	413.	*800.	276.	3.94	0.04956	1.87	3.82E 06
11.8	76.	4.09	429.	*800.	276.	3.66	0.05089	1.88	3.90E 06
16.6	81.	3.93	447.	812.	292.	3.62	0.04838	1.79	3.77E 06
21.3	86.	3.78	465.	822.	304.	3.55	0.04690	1.72	3.70E 06
27.3	92.	3.59	489.	932.	442.	4.81	0.02949	1.22	2.49E 06
32.0	98.	3.41	515.	882.	379.	3.88	0.03655	1.37	3.09E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
262	A-6B	0.2110	1463.	2097.	0.249	7.60	0.09	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	86.	3.54	290.	808.	422.	4.90	0.02325	1.63	1.38E 06
11.8	92.	3.34	307.	*900.	533.	5.79	0.01784	1.39	1.07E 06
16.6	98.	3.14	327.	922.	559.	5.71	0.01710	1.32	1.05E 06
21.3	103.	2.96	347.	997.	644.	6.23	0.01464	1.20	9.11E 05
27.3	111.	2.74	374.	1029.	680.	6.15	0.01394	1.14	8.99E 05
32.0	117.	2.55	402.	964.	607.	5.17	0.01614	1.15	1.11E 06

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
263	A-6A	0.2110	1060.	1025.	0.205	5.31	0.08	0.04	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	68.	3.82	221.	*700.	431.	6.36	0.01457	1.74	7.82E 05
11.8	73.	3.60	234.	795.	539.	7.42	0.01143	1.51	5.96E 05
21.3	81.	3.18	266.	965.	729.	8.95	0.00832	1.28	4.26E 05
26.1	86.	2.97	284.	953.	716.	8.35	0.00854	1.23	4.63E 05
30.8	90.	2.78	304.	946.	709.	7.89	0.00870	1.19	4.97E 05
35.5	94.	2.60	325.	959.	723.	7.69	0.00857	1.14	5.11E 05
40.3	100.	2.35	360.	880.	636.	6.35	0.01000	1.11	6.67E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
265	A-6A	0.2110	964.	885.	0.416	5.65	0.17	-0.06	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	61.	4.00	429.	*500.	180.	2.93	0.04776	2.09	4.46E 06
11.8	64.	3.88	442.	588.	279.	4.35	0.02651	1.61	2.60E 06
21.3	69.	3.62	473.	626.	322.	4.64	0.02260	1.43	2.22E 06
26.1	72.	3.50	490.	627.	323.	4.50	0.02274	1.41	2.25E 06
30.8	74.	3.37	509.	630.	326.	4.40	0.02270	1.39	2.27E 06
35.5	76.	3.24	529.	657.	357.	4.67	0.02045	1.27	2.06E 06
40.3	79.	3.06	560.	646.	344.	4.33	0.02163	1.28	2.75E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
266	A-6A	0.2110	1775.	1718.	0.430	5.68	0.14	0.03	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	66.	4.30	412.	*500.	178.	2.68	0.05110	1.62	5.01E 06
11.8	70.	4.20	421.	572.	259.	3.73	0.03023	1.15	4.00E 06
21.3	75.	4.01	441.	589.	278.	3.68	0.02837	1.09	3.82E 06
26.1	78.	3.92	452.	586.	274.	3.50	0.02928	1.10	3.91E 06
30.8	81.	3.82	463.	594.	284.	3.50	0.02825	1.07	3.81E 06
35.5	84.	3.73	474.	*600.	290.	3.46	0.02784	1.05	3.78E 06
40.3	88.	3.60	492.	601.	292.	3.32	0.02818	1.04	3.84E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
268	A-6A	0.2110	1811.	1785.	0.212	5.21	0.07	0.05	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	73.	4.10	213.	*600.	320.	4.36	0.02115	1.51	1.62E 06
11.8	79.	3.94	222.	643.	369.	4.68	0.01806	1.33	1.41E 06
21.3	89.	3.62	242.	711.	445.	5.01	0.01478	1.12	1.18E 06
26.1	94.	3.46	252.	712.	446.	4.77	0.01493	1.10	1.21E 06
30.8	98.	3.31	264.	704.	437.	4.44	0.01555	1.10	1.28E 06
35.5	103.	3.17	276.	734.	471.	4.57	0.01433	1.03	1.21E 06
40.3	110.	2.97	294.	724.	460.	4.19	0.01504	1.03	1.30E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
263	A-6B	0.2110	1789.	-2336.	0.205	8.47	0.14	-0.07	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	111.	1.96	431.	997.	617.	5.55	0.01680	1.61	8.02E 05
11.8	118.	1.77	476.	1100.	729.	6.19	0.01399	1.47	6.86E 05
16.6	125.	1.61	524.	1129.	760.	6.08	0.01351	1.38	6.97E 05
21.3	132.	1.47	574.	1076.	704.	5.32	0.01494	1.35	8.29E 05
27.3	142.	1.32	639.	1135.	766.	5.39	0.01375	1.25	7.96E 05
32.0	152.	1.21	701.	1039.	664.	4.38	0.01664	1.27	1.03E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
265	A-6B	0.2110	1789.	-3143.	0.416	9.03	0.25	0.00	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	86.	2.65	647.	778.	317.	3.68	0.03907	2.07	2.73E 06
11.8	89.	2.45	700.	*900.	467.	5.26	0.02408	1.48	1.70E 06
16.6	92.	2.26	760.	918.	489.	5.34	0.02294	1.40	1.67E 06
21.3	94.	2.07	827.	926.	499.	5.29	0.02256	1.35	1.71E 06
27.3	98.	1.86	923.	1031.	621.	6.36	0.01758	1.16	1.34E 06
32.0	101.	1.67	1024.	908.	476.	4.70	0.02430	1.28	2.07E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
266	A-6B	0.2110	1789.	1340.	0.430	9.06	0.18	-0.01	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	96.	3.31	535.	746.	272.	2.83	0.05158	1.77	4.31E 06
11.8	100.	3.17	558.	*800.	339.	3.39	0.03821	1.39	3.48E 06
16.6	104.	3.04	583.	817.	360.	3.46	0.03570	1.31	3.33E 06
21.3	108.	2.91	609.	822.	366.	3.39	0.03548	1.28	3.36E 06
27.3	113.	2.76	642.	882.	440.	3.90	0.02810	1.07	2.78E 06
32.0	117.	2.62	676.	847.	396.	3.38	0.03285	1.15	3.25E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL	
268	A-6B	0.2110	1789.	1740.	0.212	8.31	0.10	-0.07	
X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
7.1	123.	2.64	331.	884.	489.	3.99	0.02271	1.50	1.31E 06
11.8	130.	2.47	353.	*900.	508.	3.92	0.02203	1.43	1.31E 06
16.6	137.	2.32	377.	1008.	633.	4.63	0.01692	1.22	1.04E 06
21.3	144.	2.18	401.	1007.	633.	4.39	0.01719	1.19	1.09E 06
27.3	153.	2.03	430.	1124.	760.	4.97	0.01396	1.10	9.12E 05
32.0	161.	1.90	459.	1029.	657.	4.07	0.01699	1.13	1.15E 06

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
306	A-7	0.4382	1483.	1482.	0.065	0.36	0.01	-0.17

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	82.	3.62	17.	318.	285.	3.49	0.00175	1.21	2.64E 05
5.7	84.	3.54	18.	334.	301.	3.59	0.00165	1.14	2.51E 05
8.0	86.	3.46	18.	338.	305.	3.55	0.00163	1.12	2.51E 05
10.3	88.	3.39	18.	345.	313.	3.55	0.00160	1.09	2.48E 05
12.6	90.	3.31	19.	339.	307.	3.40	0.00166	1.11	2.57E 05
14.8	92.	3.24	19.	338.	305.	3.31	0.00158	1.10	2.62E 05
17.1	94.	3.16	20.	346.	314.	3.32	0.00153	1.07	2.58E 05
19.4	96.	3.09	20.	350.	318.	3.30	0.00162	1.04	2.58E 05
21.7	98.	3.02	21.	357.	325.	3.30	0.00159	1.02	2.56E 05
26.2	103.	2.89	21.	376.	344.	3.36	0.00149	0.94	2.47E 05
28.5	105.	2.82	22.	392.	360.	3.44	0.00141	0.90	2.38E 05
30.8	108.	2.73	23.	409.	378.	3.51	0.00133	0.85	2.30E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
308	A-7	0.4382	1471.	1470.	0.124	0.60	0.01	-0.08

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	69.	4.05	29.	309.	254.	3.67	0.00321	1.34	5.33E 05
5.7	71.	3.98	30.	331.	277.	3.88	0.00289	1.25	4.89E 05
8.0	73.	3.90	30.	338.	284.	3.86	0.00282	1.22	4.80E 05
10.3	76.	3.83	31.	356.	302.	4.00	0.00263	1.16	4.51E 05
12.6	78.	3.76	31.	365.	311.	4.02	0.00255	1.12	4.40E 05
14.8	80.	3.69	32.	362.	309.	3.89	0.00260	1.13	4.50E 05
17.1	81.	3.62	33.	380.	327.	4.01	0.00243	1.05	4.26E 05
19.4	83.	3.55	33.	390.	337.	4.04	0.00235	1.03	4.15E 05
21.7	85.	3.48	34.	395.	343.	4.02	0.00232	1.01	4.12E 05
26.2	89.	3.35	35.	396.	343.	3.86	0.00235	0.99	4.23E 05
28.5	91.	3.28	36.	412.	359.	3.96	0.00223	0.95	4.06E 05
30.8	93.	3.18	37.	417.	364.	3.90	0.00221	0.93	4.07E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
310	A-7	0.4382	1529.	1528.	0.214	0.86	0.02	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	63.	4.30	48.	304.	226.	3.60	0.00521	1.32	1.03E 06
5.7	65.	4.24	48.	325.	247.	3.83	0.00455	1.23	9.45E 05
8.0	66.	4.18	49.	325.	247.	3.72	0.00471	1.24	9.55E 05
10.3	68.	4.12	50.	345.	268.	3.92	0.00425	1.16	8.82E 05
12.6	70.	4.06	50.	353.	275.	3.93	0.00414	1.13	8.61E 05
14.8	72.	4.00	51.	342.	264.	3.68	0.00442	1.18	9.09E 05
17.1	74.	3.94	52.	360.	283.	3.84	0.00407	1.11	8.49E 05
19.4	75.	3.88	53.	371.	295.	3.91	0.00388	1.07	8.17E 05
21.7	77.	3.82	53.	371.	294.	3.82	0.00392	1.07	8.26E 05
26.2	80.	3.71	55.	367.	291.	3.62	0.00405	1.08	8.52E 05
28.5	82.	3.65	56.	387.	311.	3.79	0.00373	1.01	7.97E 05
30.8	84.	3.57	57.	383.	307.	3.64	0.00384	1.02	8.21E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
315	A-7	0.4382	1424.	1423.	0.272	0.96	0.02	-0.11

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	58.	4.41	59.	290.	201.	3.48	0.00665	1.34	1.40E 06
5.7	59.	4.35	60.	313.	225.	3.78	0.00575	1.25	1.27E 05
8.0	61.	4.30	60.	315.	227.	3.73	0.00573	1.26	1.27E 06
10.3	63.	4.24	61.	333.	246.	3.92	0.00521	1.19	1.17E 06
12.6	64.	4.19	62.	343.	256.	3.98	0.00498	1.16	1.13E 06
14.8	66.	4.13	63.	332.	245.	3.71	0.00533	1.20	1.19E 06
17.1	68.	4.08	64.	348.	262.	3.87	0.00492	1.14	1.12E 06
19.4	69.	4.03	64.	355.	269.	3.89	0.00478	1.12	1.09E 06
21.7	71.	3.97	65.	359.	273.	3.86	0.00473	1.10	1.08E 06
26.2	74.	3.87	67.	355.	268.	3.64	0.00491	1.12	1.11E 06
28.5	75.	3.81	68.	371.	285.	3.79	0.00455	1.06	1.05E 06
30.8	77.	3.73	70.	376.	290.	3.76	0.00449	1.04	1.04E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
316	A-7	0.4382	1444.	1443.	0.361	1.13	0.03	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	59.	4.36	79.	294.	189.	3.19	0.00858	1.31	1.95E 06
5.7	61.	4.32	80.	312.	208.	3.43	0.00757	1.23	1.82E 05
8.0	62.	4.27	81.	312.	208.	3.35	0.00765	1.24	1.83E 06
10.3	64.	4.22	82.	330.	227.	3.56	0.00685	1.18	1.70E 06
12.6	65.	4.17	83.	336.	233.	3.58	0.00655	1.16	1.67E 05
14.8	67.	4.13	83.	324.	221.	3.32	0.00723	1.21	1.76E 06
17.1	68.	4.08	84.	340.	237.	3.49	0.00651	1.15	1.65E 06
19.4	69.	4.03	85.	350.	248.	3.58	0.00625	1.11	1.59E 06
21.7	71.	3.98	86.	351.	249.	3.52	0.00629	1.11	1.59E 06
26.2	73.	3.89	89.	346.	244.	3.33	0.00655	1.13	1.64E 06
28.5	75.	3.84	90.	362.	261.	3.49	0.00603	1.07	1.54E 06
30.8	77.	3.77	91.	367.	265.	3.46	0.00594	1.05	1.53E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
318	A-7	0.4382	1599.	1598.	0.344	1.46	0.03	-0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	58.	4.48	73.	371.	240.	4.15	0.00793	1.41	1.56E 06
5.7	60.	4.42	74.	401.	272.	4.53	0.00683	1.29	1.38E 05
8.0	62.	4.35	76.	398.	268.	4.33	0.00700	1.30	1.41E 06
10.3	64.	4.29	77.	415.	286.	4.48	0.00651	1.24	1.32E 06
12.6	66.	4.23	78.	427.	299.	4.54	0.00521	1.20	1.27E 06
14.8	68.	4.17	79.	414.	285.	4.19	0.00557	1.25	1.35E 06
17.1	70.	4.10	80.	429.	301.	4.31	0.00625	1.19	1.27E 06
19.4	72.	4.04	81.	437.	309.	4.31	0.00610	1.17	1.25E 06
21.7	74.	3.98	83.	443.	316.	4.29	0.00599	1.14	1.23E 06
26.2	77.	3.86	85.	437.	309.	4.00	0.00625	1.16	1.28E 06
28.5	79.	3.80	87.	459.	332.	4.21	0.00573	1.08	1.19E 06
30.8	82.	3.71	89.	498.	372.	4.56	0.00501	0.98	1.05E 06

TABLE I. - Continued. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
320	A-7	0.4382	1437.	1435.	0.381	1.73	0.03	0.01

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	60.	4.34	84.	416.	262.	4.38	0.00848	1.54	1.52E 06
5.7	62.	4.28	85.	433.	281.	4.53	0.00785	1.47	1.42E 06
8.0	64.	4.21	87.	426.	273.	4.27	0.00820	1.50	1.47E 06
10.3	66.	4.14	88.	435.	283.	4.28	0.00793	1.46	1.43E 06
12.6	68.	4.07	90.	448.	296.	4.34	0.00754	1.41	1.36E 06
14.8	70.	4.00	91.	429.	276.	3.94	0.00833	1.49	1.49E 06
17.1	72.	3.93	93.	445.	293.	4.06	0.00778	1.42	1.41E 06
19.4	74.	3.86	94.	444.	292.	3.95	0.00788	1.42	1.42E 06
21.7	76.	3.79	96.	451.	300.	3.95	0.00768	1.38	1.40E 06
26.2	80.	3.66	99.	440.	288.	3.62	0.00825	1.43	1.50E 06
28.5	81.	3.59	101.	463.	312.	3.83	0.00747	1.32	1.38E 06
30.8	84.	3.50	104.	577.	432.	5.14	0.00498	1.00	9.35E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
322	A-7	0.4382	1288.	1286.	0.408	1.23	0.03	0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	60.	4.27	91.	302.	188.	3.16	0.00944	1.37	2.19E 06
5.7	61.	4.23	92.	310.	196.	3.22	0.00897	1.34	2.12E 06
8.0	62.	4.18	93.	304.	191.	3.05	0.00947	1.38	2.19E 06
10.3	64.	4.13	94.	308.	195.	3.06	0.00924	1.36	2.15E 06
12.6	65.	4.08	95.	309.	196.	3.01	0.00929	1.37	2.16E 06
14.8	66.	4.03	96.	298.	184.	2.77	0.01029	1.44	2.28E 06
17.1	68.	3.99	98.	316.	204.	3.00	0.00895	1.35	2.10E 06
19.4	69.	3.94	99.	336.	224.	3.24	0.00787	1.27	1.92E 06
21.7	70.	3.89	100.	335.	223.	3.16	0.00799	1.27	1.94E 06
26.2	73.	3.80	102.	334.	222.	3.05	0.00813	1.28	1.97E 06
28.5	74.	3.75	104.	352.	241.	3.25	0.00731	1.20	1.82E 06
30.8	76.	3.68	106.	357.	246.	3.24	0.00718	1.18	1.80E 06

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
324	A-7	0.4382	1453.	1452.	0.118	0.73	0.01	-0.07

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	71.	3.97	28.	397.	333.	4.68	0.00274	1.34	3.74E 05
5.7	74.	3.88	29.	440.	377.	5.11	0.00237	1.21	3.25E 05
8.0	76.	3.79	30.	437.	374.	4.90	0.00242	1.21	3.33E 05
10.3	79.	3.70	31.	464.	402.	5.09	0.00223	1.14	3.09E 05
12.6	81.	3.61	31.	493.	431.	5.30	0.00207	1.07	2.87E 05
14.8	84.	3.52	32.	475.	413.	4.93	0.00220	1.09	3.09E 05
17.1	86.	3.43	33.	*500.	438.	5.09	0.00205	1.03	2.91E 05
19.4	88.	3.35	34.	524.	463.	5.24	0.00193	0.99	2.76E 05
21.7	91.	3.27	35.	523.	462.	5.09	0.00195	0.98	2.82E 05
26.2	95.	3.10	36.	526.	465.	4.88	0.00196	0.95	2.91E 05
28.5	97.	3.02	37.	565.	505.	5.18	0.00178	0.90	2.67E 05
30.8	101.	2.91	39.	574.	515.	5.10	0.00176	0.88	2.68E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
328	A-7	0.4382	1483.	1481.	0.234	1.36	0.02	-0.06

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	63.	4.25	53.	396.	276.	4.36	0.00627	1.68	9.04E 05
5.7	66.	4.16	54.	439.	321.	4.86	0.00525	1.49	7.64E 05
8.0	69.	4.08	55.	442.	325.	4.73	0.00523	1.47	7.63E 05
10.3	71.	3.99	56.	493.	377.	5.30	0.00439	1.30	6.40E 05
12.6	74.	3.91	57.	532.	418.	5.67	0.00392	1.20	5.69E 05
14.8	76.	3.82	59.	504.	388.	5.10	0.00431	1.26	6.34E 05
17.1	79.	3.74	60.	532.	417.	5.32	0.00398	1.18	5.86E 05
19.4	81.	3.65	61.	557.	444.	5.49	0.00372	1.12	5.49E 05
21.7	83.	3.57	63.	555.	442.	5.31	0.00377	1.11	5.63E 05
26.2	88.	3.41	66.	553.	440.	5.02	0.00383	1.10	5.85E 05
28.5	90.	3.33	67.	*600.	489.	5.45	0.00339	1.02	5.18E 05
30.8	93.	3.21	70.	602.	492.	5.29	0.00340	1.00	5.29E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
330	A-7	0.4382	1679.	1678.	0.171	1.45	0.01	-0.00

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	77.	3.91	42.	520.	399.	5.17	0.00441	1.56	4.78E 05
5.7	81.	3.80	43.	543.	423.	5.24	0.00415	1.48	4.53E 05
8.0	84.	3.68	44.	550.	430.	5.11	0.00411	1.44	4.53E 05
10.3	88.	3.57	46.	627.	511.	5.84	0.00337	1.29	3.71E 05
12.6	91.	3.46	47.	689.	577.	6.35	0.00295	1.20	3.23E 05
14.8	94.	3.35	49.	659.	546.	5.80	0.00317	1.21	3.57E 05
17.1	97.	3.25	50.	694.	582.	5.98	0.00295	1.16	3.36E 05
19.4	101.	3.15	52.	681.	569.	5.66	0.00306	1.15	3.55E 05
21.7	104.	3.05	54.	732.	623.	6.00	0.00277	1.09	3.23E 05
26.2	110.	2.86	57.	707.	596.	5.41	0.00296	1.08	3.59E 05
28.5	113.	2.78	59.	759.	652.	5.76	0.00258	1.02	3.27E 05
30.8	118.	2.66	62.	788.	682.	5.79	0.00255	0.99	3.19E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
358	A-7	0.4382	2713.	2711.	0.071	0.53	0.00	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	79.	4.36	16.	354.	307.	3.89	0.00231	1.18	3.07E 05
5.7	82.	4.27	16.	365.	318.	3.86	0.00224	1.14	3.03E 05
8.0	86.	4.19	16.	379.	333.	3.88	0.00214	1.09	2.95E 05
10.3	89.	4.10	17.	392.	346.	3.88	0.00205	1.04	2.89E 05
12.6	93.	4.02	17.	393.	346.	3.74	0.00208	1.04	2.92E 05
14.8	96.	3.94	17.	403.	357.	3.72	0.00202	1.01	2.87E 05
17.1	99.	3.86	18.	415.	369.	3.72	0.00195	0.98	2.82E 05
19.4	102.	3.78	18.	412.	366.	3.57	0.00201	0.99	2.88E 05
21.7	106.	3.70	18.	428.	382.	3.61	0.00192	0.95	2.80E 05
26.2	112.	3.56	19.	434.	388.	3.47	0.00191	0.93	2.82E 05
28.5	115.	3.49	20.	435.	389.	3.38	0.00193	0.92	2.85E 05
30.8	119.	3.39	20.	441.	395.	3.30	0.00192	0.91	2.86E 05

TABLE I. - Concluded. HEAT-TRANSFER DATA FOR CRYOGENIC HYDROGEN FROM 1000 TO 2500 PSIA

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
370	A-7	0.4382	2544.	2543.	0.119	0.76	0.01	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	69.	4.53	25.	359.	292.	4.21	0.00337	1.19	5.15E 05
5.7	73.	4.45	26.	381.	314.	4.33	0.00311	1.11	4.91E 05
8.0	76.	4.37	26.	376.	309.	4.08	0.00322	1.13	5.03E 05
10.3	78.	4.30	26.	394.	328.	4.18	0.00301	1.07	4.83E 05
12.6	81.	4.23	27.	409.	343.	4.21	0.00288	1.02	4.68E 05
14.8	84.	4.15	27.	396.	329.	3.90	0.00307	1.06	4.91E 05
17.1	87.	4.08	28.	412.	346.	3.96	0.00291	1.01	4.74E 05
19.4	90.	4.00	28.	426.	361.	4.00	0.00278	0.97	4.60E 05
21.7	93.	3.93	29.	425.	359.	3.86	0.00283	0.98	4.67E 05
26.2	99.	3.79	30.	422.	356.	3.62	0.00292	0.98	4.80E 05
28.5	101.	3.72	31.	445.	379.	3.74	0.00271	0.92	4.57E 05
30.8	105.	3.62	31.	449.	384.	3.64	0.00271	0.91	4.59E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
385	A-7	0.4382	1373.	1372.	0.213	0.82	0.02	0.05

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	69.	4.00	51.	310.	235.	3.41	0.00490	1.32	9.75E 05
5.7	71.	3.95	52.	344.	270.	3.83	0.00408	1.18	8.40E 05
8.0	72.	3.89	52.	339.	265.	3.67	0.00423	1.20	8.67E 05
10.3	74.	3.83	53.	356.	282.	3.83	0.00391	1.13	8.10E 05
12.6	75.	3.77	54.	378.	305.	4.05	0.00355	1.05	7.45E 05
14.8	77.	3.71	55.	367.	294.	3.83	0.00375	1.09	7.86E 05
17.1	78.	3.65	56.	365.	292.	3.72	0.00383	1.09	8.02E 05
19.4	80.	3.60	57.	405.	333.	4.17	0.00323	0.96	6.90E 05
21.7	81.	3.54	57.	377.	304.	3.73	0.00357	1.04	7.79E 05
26.2	84.	3.43	59.	402.	330.	3.92	0.00332	0.96	7.20E 05
28.5	86.	3.37	60.	420.	348.	4.06	0.00312	0.91	6.82E 05
30.8	88.	3.29	62.	403.	331.	3.76	0.00337	0.94	7.40E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
387	A-7	0.4382	1271.	1270.	0.189	1.12	0.02	-0.03

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	63.	4.14	44.	411.	313.	4.95	0.00444	1.65	5.81E 05
5.7	66.	4.05	45.	427.	330.	5.01	0.00420	1.57	5.50E 05
8.0	68.	3.96	46.	428.	331.	4.84	0.00423	1.56	5.55E 05
10.3	71.	3.86	47.	453.	357.	5.04	0.00388	1.45	5.10E 05
12.6	73.	3.77	48.	471.	375.	5.12	0.00369	1.39	4.85E 05
14.8	76.	3.68	49.	471.	375.	4.96	0.00372	1.38	4.95E 05
17.1	78.	3.59	50.	514.	419.	5.38	0.00327	1.26	4.34E 05
19.4	80.	3.50	52.	532.	438.	5.47	0.00312	1.21	4.18E 05
21.7	82.	3.41	53.	573.	480.	5.84	0.00281	1.13	3.76E 05
26.2	87.	3.23	56.	549.	455.	5.25	0.00303	1.13	4.21E 05
28.5	89.	3.14	58.	551.	457.	5.16	0.00303	1.11	4.27E 05
30.8	92.	3.02	60.	535.	441.	4.80	0.00320	1.12	4.63E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
388	A-7	0.4382	1352.	1351.	0.119	0.89	0.01	-0.02

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	69.	3.98	29.	421.	345.	4.98	0.00317	1.65	3.43E 05
5.7	72.	3.86	29.	466.	390.	5.39	0.00275	1.49	2.98E 05
8.0	75.	3.75	30.	474.	399.	5.29	0.00271	1.46	2.95E 05
10.3	78.	3.64	31.	484.	409.	5.22	0.00265	1.41	2.92E 05
12.6	81.	3.53	32.	515.	440.	5.42	0.00244	1.32	2.71E 05
14.8	84.	3.42	33.	*500.	426.	5.07	0.00257	1.34	2.90E 05
17.1	87.	3.31	34.	516.	442.	5.09	0.00247	1.28	2.82E 05
19.4	89.	3.21	35.	545.	471.	5.27	0.00230	1.21	2.66E 05
21.7	92.	3.10	37.	554.	481.	5.22	0.00226	1.18	2.55E 05
26.2	97.	2.91	39.	547.	474.	4.86	0.00234	1.16	2.85E 05
28.5	100.	2.82	40.	583.	511.	5.11	0.00214	1.09	2.64E 05
30.8	104.	2.68	42.	602.	530.	5.09	0.00207	1.05	2.62E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
391	A-7	0.4382	2323.	2321.	0.199	0.72	0.01	-0.05

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	65.	4.56	42.	273.	207.	3.18	0.00499	1.11	9.97E 05
5.7	67.	4.52	42.	289.	223.	3.33	0.00454	1.03	9.85E 05
8.0	69.	4.47	42.	297.	232.	3.38	0.00434	0.98	9.79E 05
10.3	70.	4.42	43.	304.	239.	3.39	0.00421	0.96	9.73E 05
12.6	72.	4.38	43.	322.	257.	3.56	0.00384	0.89	9.40E 05
14.8	74.	4.34	44.	310.	245.	3.32	0.00415	0.94	9.73E 05
17.1	75.	4.29	44.	305.	240.	3.18	0.00431	0.96	9.90E 05
19.4	77.	4.24	45.	334.	270.	3.50	0.00369	0.85	9.26E 05
21.7	79.	4.20	45.	315.	250.	3.17	0.00415	0.93	9.82E 05
26.2	82.	4.11	46.	333.	268.	3.26	0.00382	0.86	9.49E 05
28.5	84.	4.07	47.	342.	278.	3.31	0.00367	0.83	9.30E 05
30.8	86.	4.00	47.	331.	267.	3.09	0.00393	0.87	9.67E 05

RUN	T.S.	I.D.	P-IN	P-OUT	WT.FLOW	HT.FLUX	MACH	HT.BAL
393	A-7	0.4382	1898.	1897.	0.074	0.53	0.01	-0.04

X/D	TB	RHOB	VELOC	TO	TI	TI/TB	H	HEX/HC	RE-FILM
3.4	77.	4.06	17.	379.	324.	4.23	0.00252	1.50	2.77E 05
5.7	80.	3.94	18.	376.	321.	3.99	0.00250	1.51	2.84E 05
8.0	84.	3.83	18.	380.	325.	3.86	0.00250	1.49	2.85E 05
10.3	88.	3.72	19.	380.	325.	3.71	0.00263	1.48	2.90E 05
12.6	91.	3.61	20.	394.	338.	3.71	0.00253	1.42	2.82E 05
14.8	95.	3.51	20.	415.	360.	3.81	0.00236	1.33	2.69E 05
17.1	98.	3.41	21.	467.	413.	4.22	0.00199	1.17	2.33E 05
19.4	101.	3.31	21.	531.	478.	4.72	0.00167	1.05	2.00E 05
21.7	105.	3.21	22.	573.	521.	4.98	0.00152	0.98	1.83E 05
26.2	111.	3.03	23.	527.	474.	4.25	0.00174	1.02	2.15E 05
28.5	115.	2.94	24.	490.	437.	3.81	0.00195	1.07	2.42E 05
30.8	119.	2.82	25.	466.	412.	3.45	0.00215	1.11	2.67E 05

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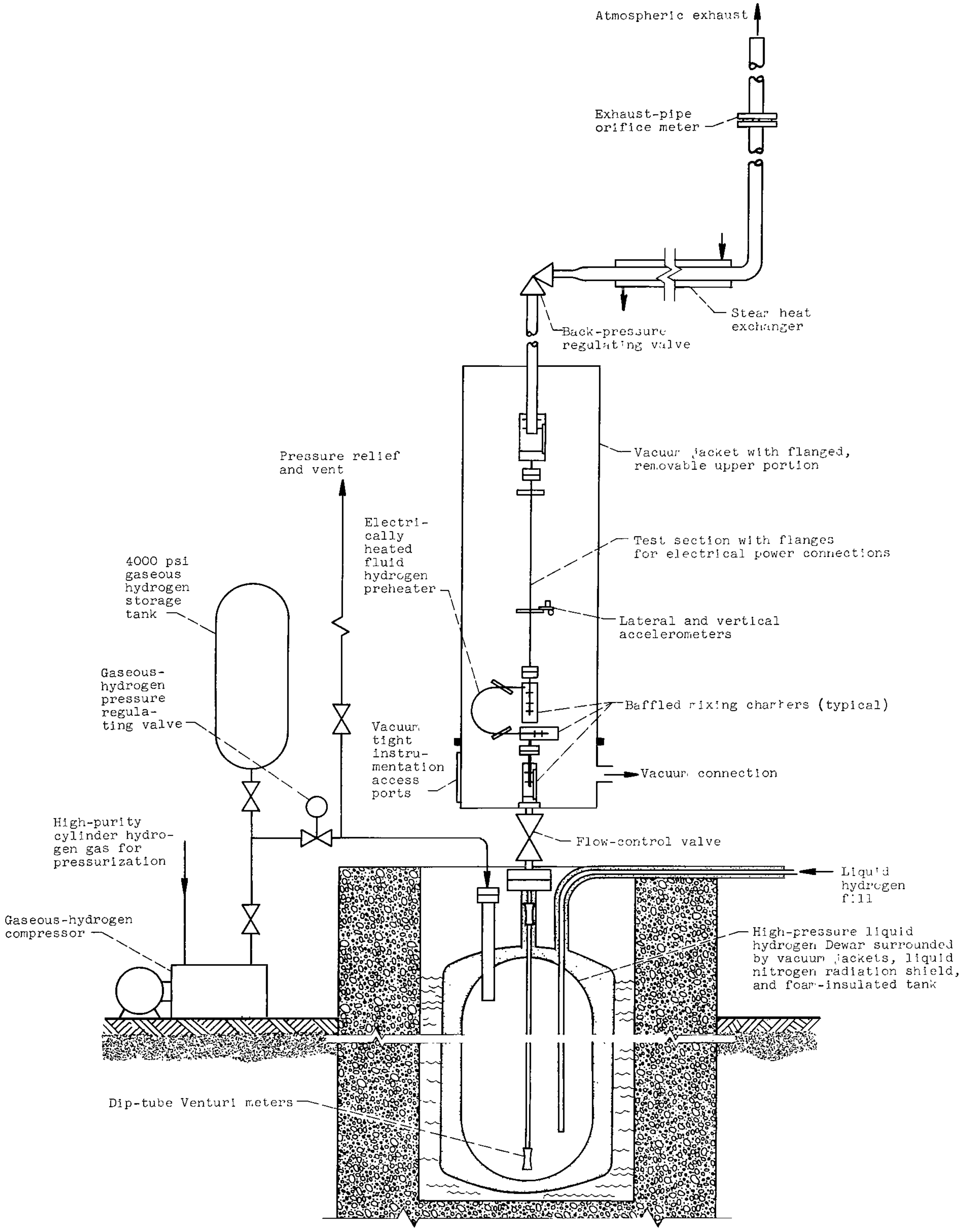
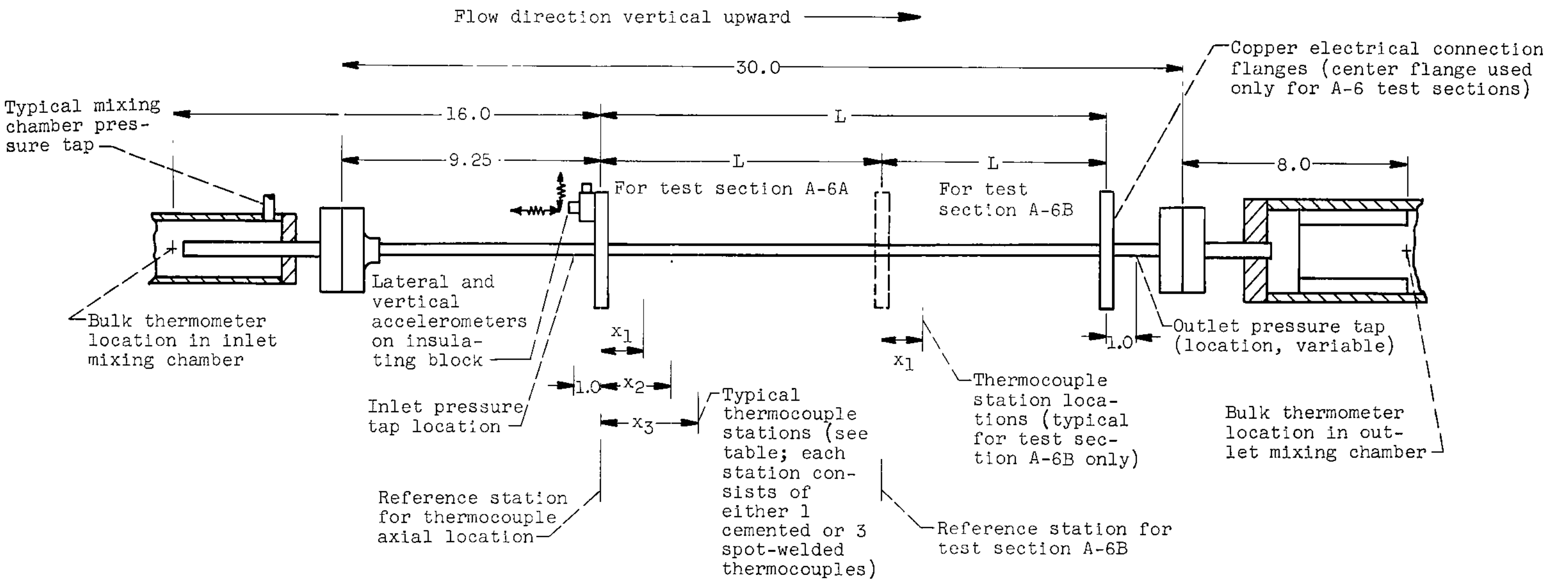


Figure 1. - Schematic diagram of 3000 psi cryogenic-hydrogen heat-transfer test installation.



Test section	External diameter of tube, d_o	Internal diameter of tube, d_i	Length of test section, L	Thermocouple axial station locations, x											
				1	2	3	4	5	6	7	8	9	10	11	12
A-4	0.375	0.315	18.0	[a]1.5w	2.5	4.5	5.5w	6.5	8.5	9.5w	10.5	12.5w	13.5	14.5	16.5w
A-5	.251	.211	18.0	1.5w	2.5	4.5	5.5w	6.5	8.5	9.5w	10.5	12.5w	13.5	14.5	16.5w
A-6A	.251	.211	10.0	1.5w	2.5	4.5	5.5w	6.5	7.5w	8.5	----	-----	----	----	-----
A-6B	.251	.211	8.0 (center flange reference)	1.5	2.5w	3.5	4.5	5.75w	6.75	----	----	-----	----	----	-----
A-7	.501	.438	15.0	1.5w	2.5	3.5	4.5w	5.5	6.5	7.5w	8.5	9.5w	11.5	12.5	13.5w

[a]Where station consisted of 3 spot-welded thermocouples, location is followed by letter w. All other stations are single cemented thermocouples.

Figure 2. - Inconel heat-transfer test section showing principal instrumentation. All dimensions are in inches.

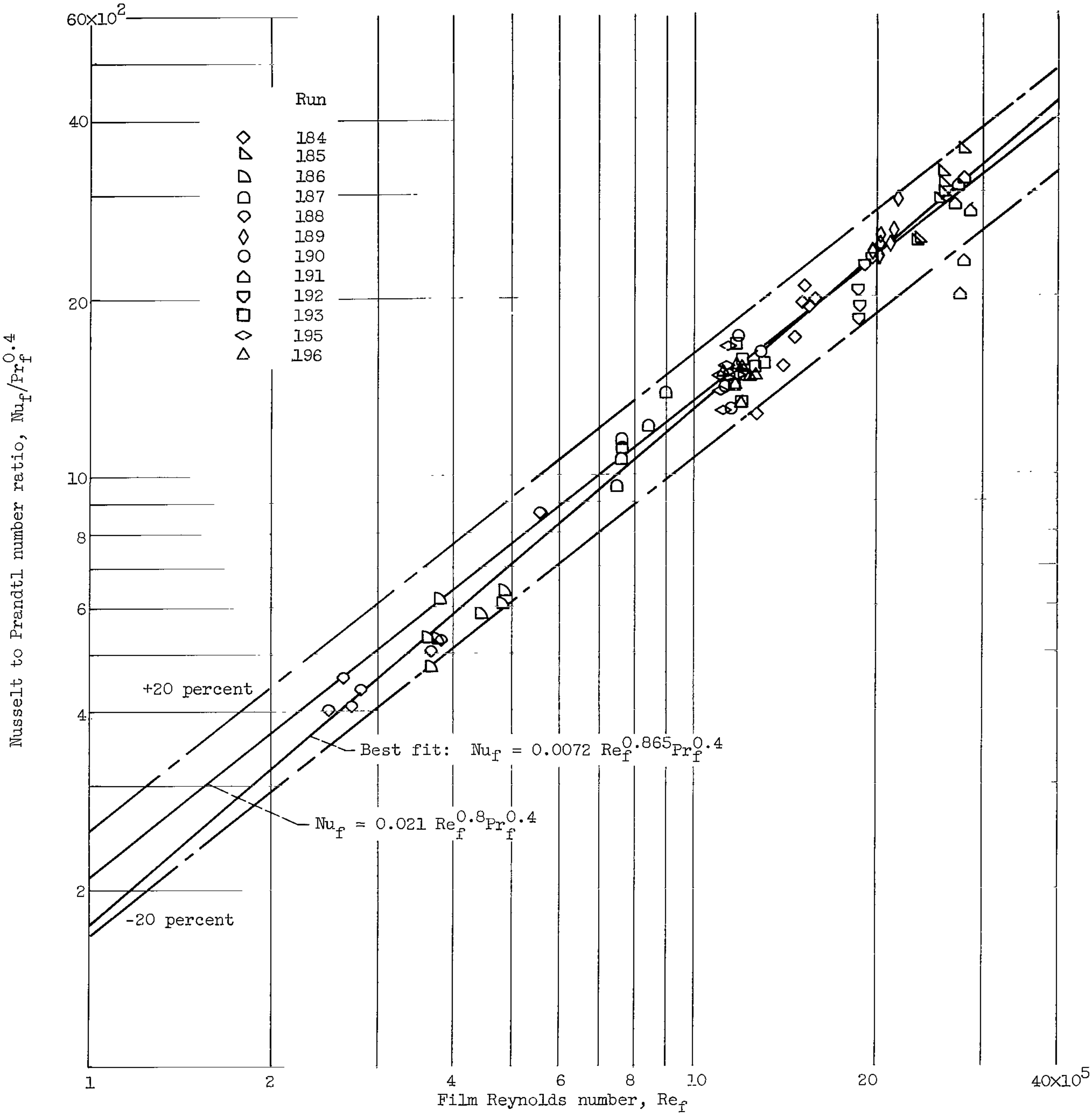


Figure 3. - Local heat-transfer results for 0.211-inch-inside-diameter tube. Length-to-diameter ratio, 30 to 69; local heat flux, 1 to 2.5 Btu per square inch per second; pressure, 1430 to 1650 psia.

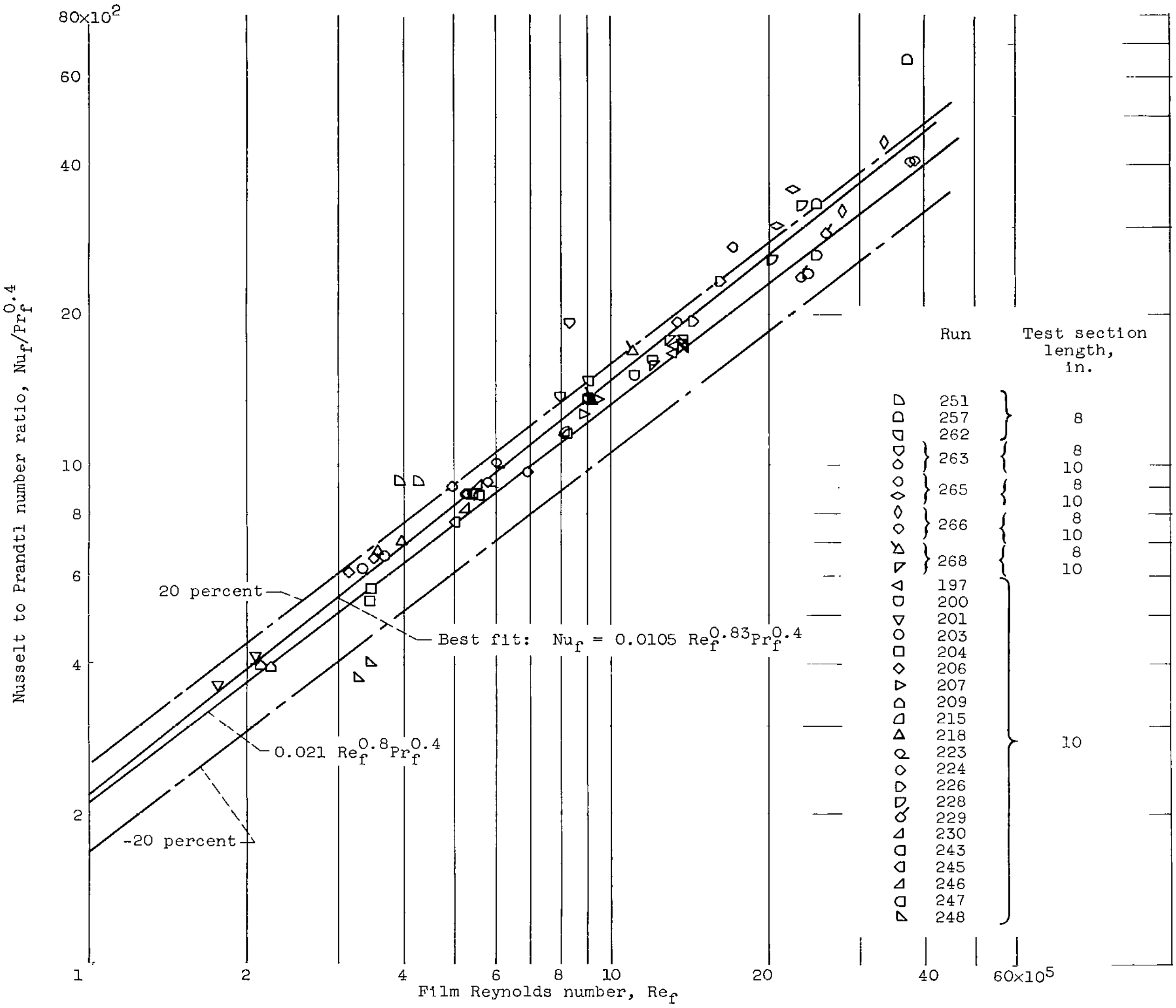


Figure 4. - Local heat-transfer results for 0.211-inch-inside-diameter tube in dual test section. 10-Inch test section: length-to-diameter ratio, 30 to 36; local heat flux, 2.1 to 6.9 Btu per square inch per second; pressure, 980 to 2200 psia. 8-Inch test section: length-to-diameter ratio, 21 to 28; local heat flux, 7.8 to 10.2 Btu per square inch per second; pressure, 1070 to 2150 psia.

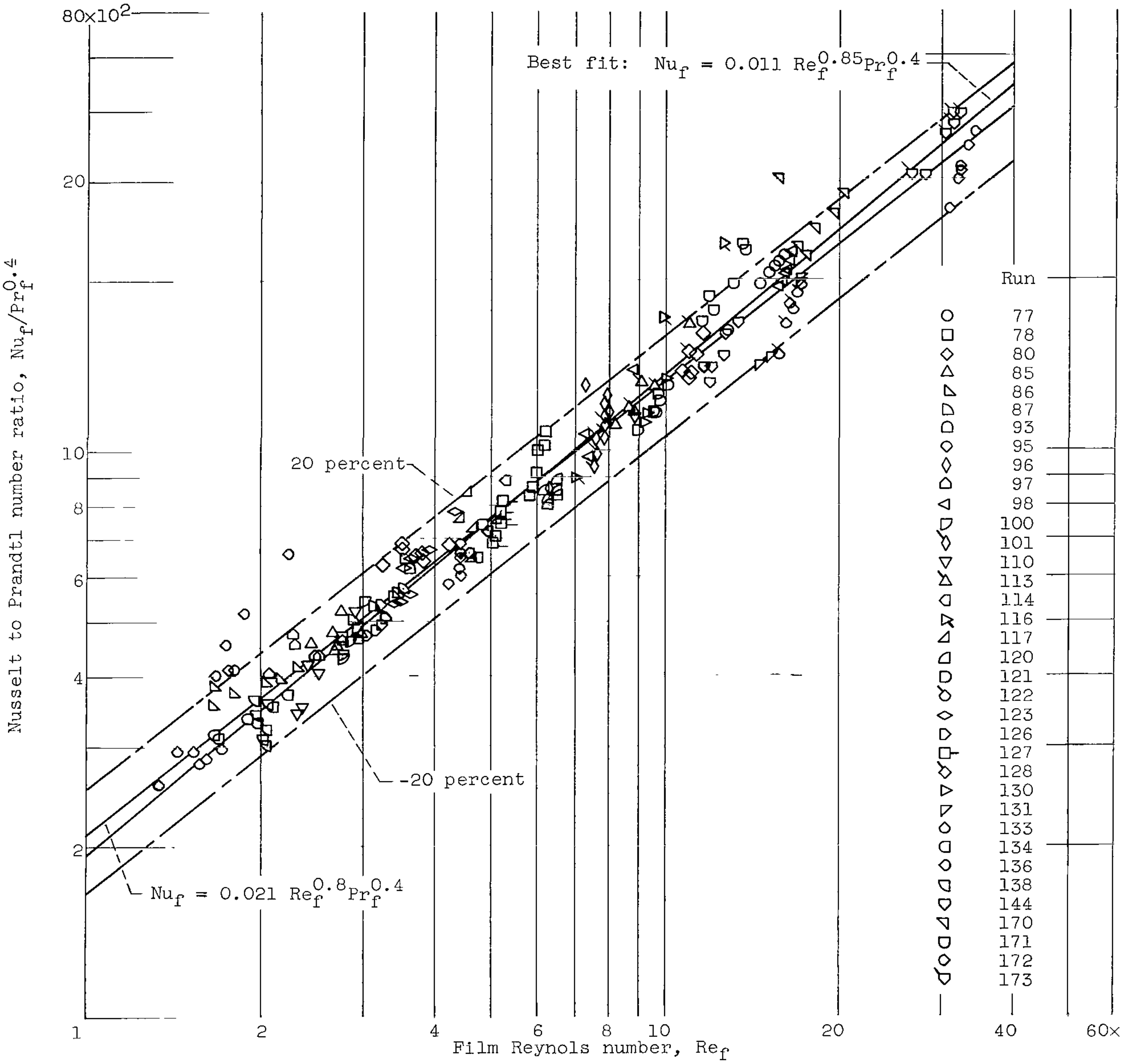


Figure 5. - Local heat-transfer results for 0.315-inch-inside-diameter tube. Length-to-diameter ratio, 27 to 46; local heat flux, 1 to 3 Btu per square inch per second; pressure, 700 to 2250 psia.

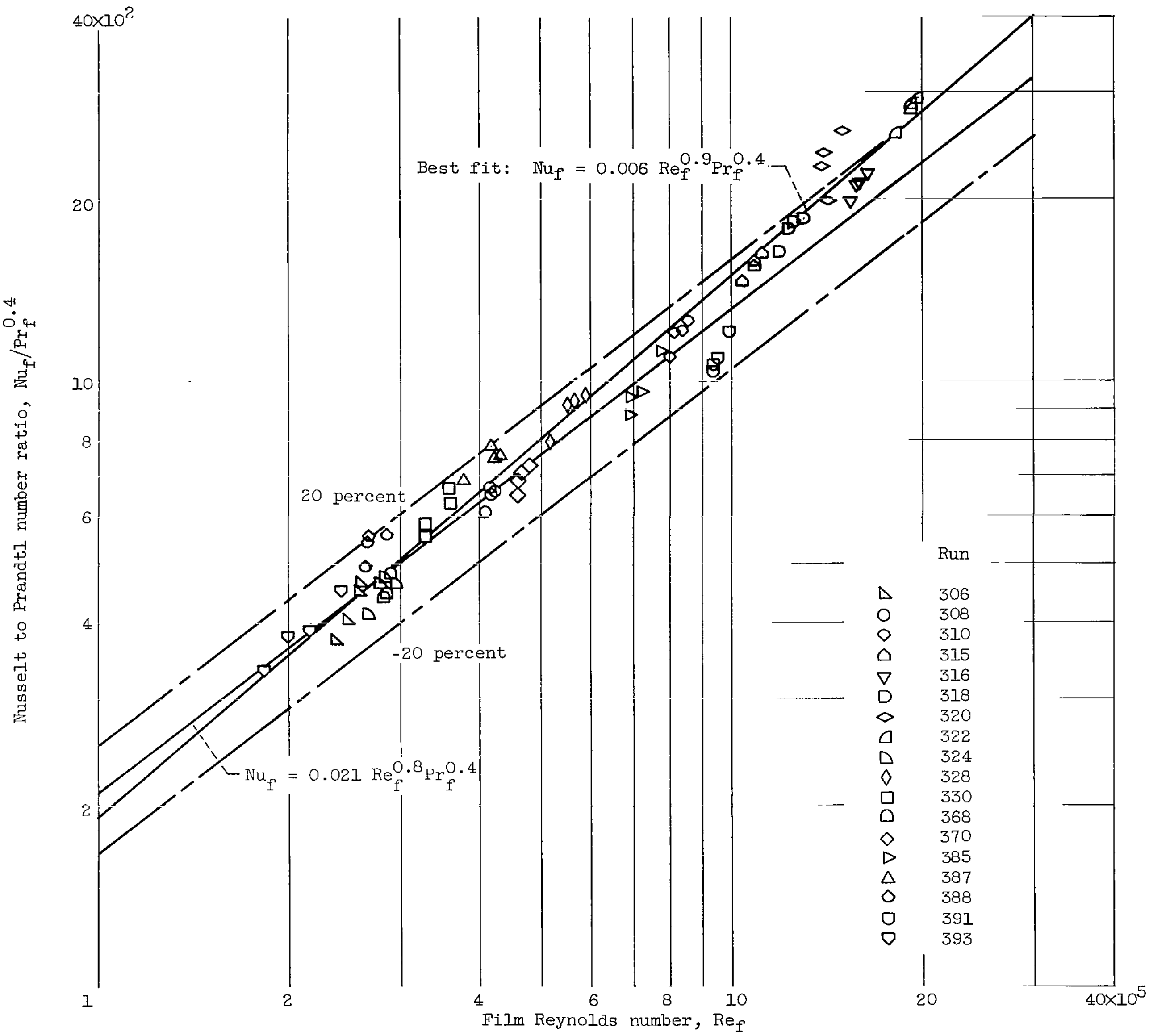


Figure 6. - Local heat-transfer results for a 0.438-inch-inside-diameter tube. No effective lateral oscillations. Length-to-diameter ratio, 19 to 29; local heat flux, 0.35 to 1.8 Btu per square inch per second; pressure, 1425 to 2700 psia.

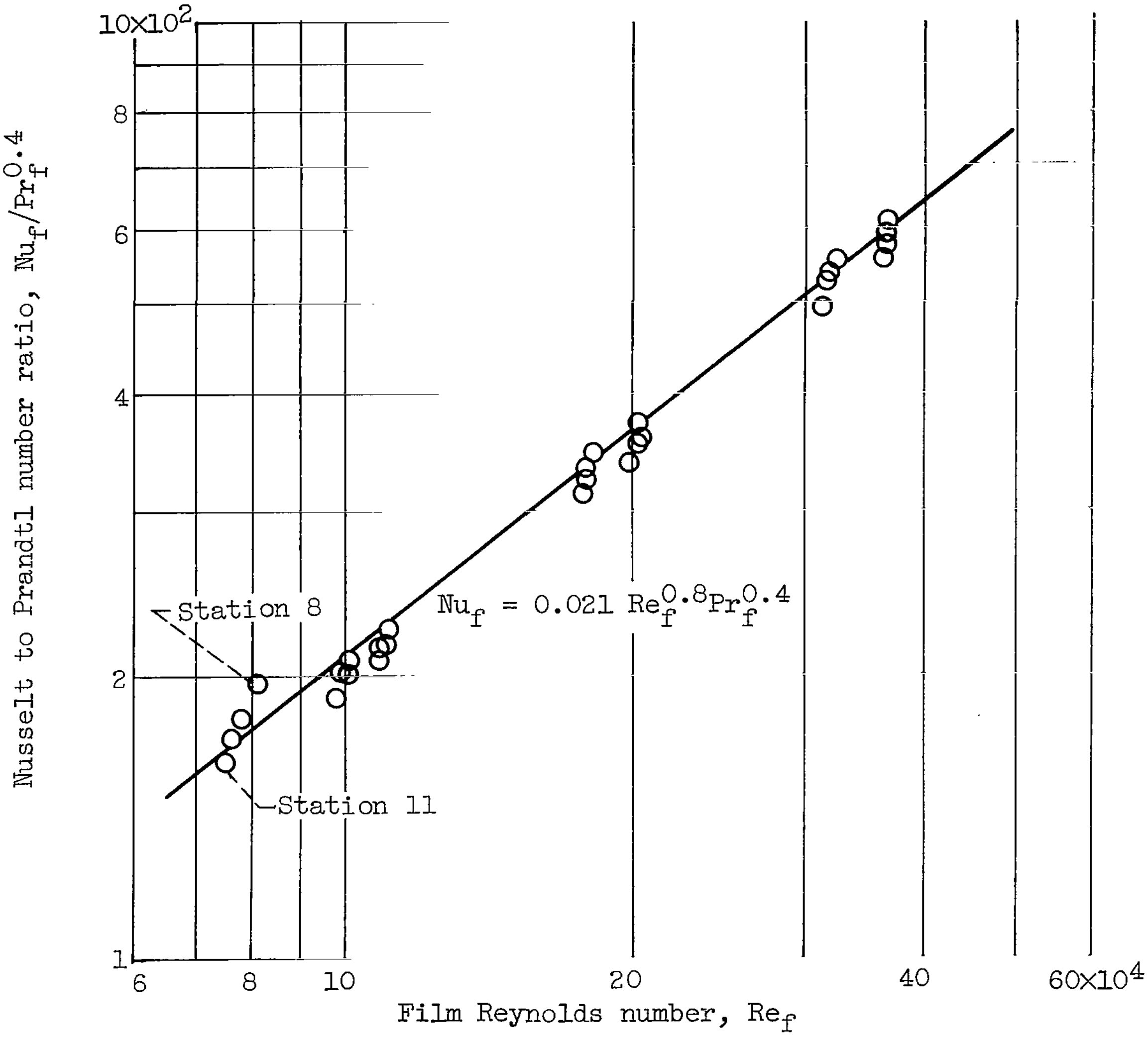


Figure 7. - Local heat-transfer results for gaseous hydrogen in 0.438-inch-inside-diameter tube. Nominal pressure, 1000 to 1600 psia; runs 269, 272, 273, 274, 276, 277, and 379.

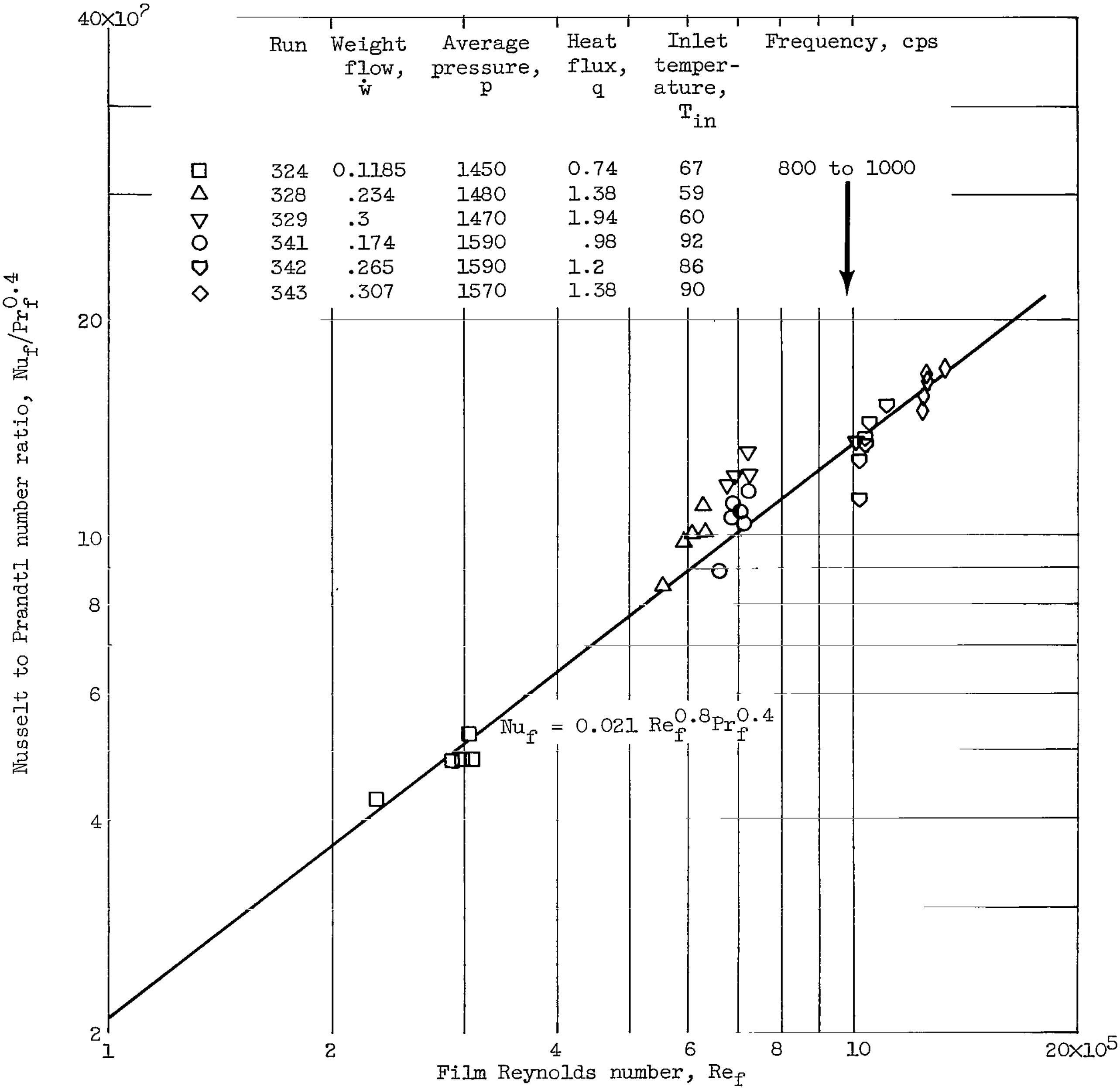


Figure 8. - Heat-transfer results for a 0.438-inch-inside-diameter tube with system oscillations. Transducer parallel to basic flow.

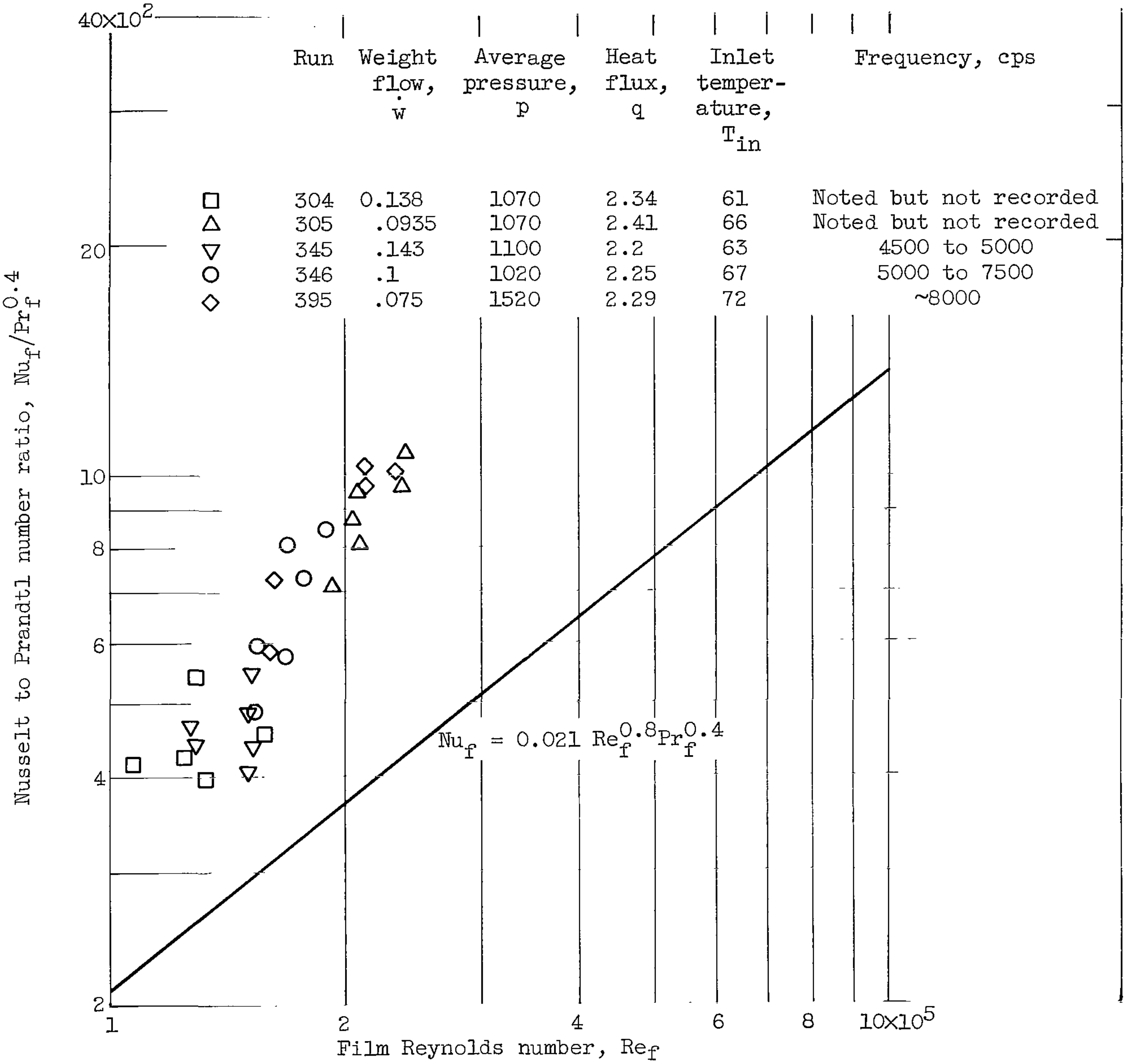


Figure 9. - Heat-transfer results for a 0.438-inch-inside-diameter tube with high-frequency lateral oscillations. Transducer normal to basic flow.

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